

CRASH INJURY EVALUATION

AD 664146

U.S. ARMY

YHC-1B CHINOOK MOCKUP

Morton, Pennsylvania

27 January 1960



AVIATION CRASH INJURY RESEARCH

A DIVISION OF
FLIGHT SAFETY FOUNDATION, Inc.

2713 EAST AIRLINE WAY

• SKY HARBOR AIRPORT •

PHOENIX, ARIZONA

TREC Technical Report 60-54

COPY NO. 3

This document has been approved
for public release and sale;
its distribution is unlimited

93

YHC-1B U. S. ARMY "CHINOOK" MOCKUP EVALUATION
Morton, Pennsylvania
27 January 1960

REPORT OF CRASH INJURY EVALUATION
AvCIR-13-PV-118
September 1960

FOR

United States Army
Transportation Research Command
Contract DA-44-177-TC-624

AVIATION CRASH INJURY RESEARCH
A Division of
Flight Safety Foundation, Inc.
2713 East Airline Way
Sky Harbor Airport
Phoenix, Arizona

Reproduction of the paper, in whole or in part, is
permitted for any purpose of the United States Government.

TREC Technical Report 60-54

VERTOL YHC-1B U. S. ARMY "CHINOOK"

MOCKUP

C R A S H I N J U R Y
E V A L U A T I O N

Jack Carroll

William R. Knowles

TABLE OF CONTENTS

	Page
FOREWORD	1
BACKGRCUND	2
SUMMARY	3
DESCRIPTION OF AIRCRAFT	5
 <u>SECTION</u>	
I EVALUATION OF BASIC AIRFRAME	7
General Discussion	7
Cockpit Fuselage	7
Cabin Fuselage	9
Aft Fuselage	11
Conclusions	14
Recommendations	14
II EVALUATION OF CREW COMPARTMENT	17
General Discussion	17
Pilot's and Copilot's Seats	19
Crew Chief/Troop Commander Seat	28
Emergency Exits	31
Other Equipment	32
Conclusions	34
Recommendations	34

III	EVALUATION OF MAIN CABIN	Page 37
	General Discussion	37
	Troop Seats	38
	Litters	47
	Emergency Exits	50
	Miscellaneous	58
	Conclusions	58
	Recommendations	59
IV	ANALYSIS OF SPECIFICATIONS AND DEVIATIONS	61
	Crash Landing	61
	Requirements and Deviations	61
	Analysis	62
	Emergency Lights	67
	Requirements and Deviations	67, 68
	Analysis	68
	Conclusions	69
	Recommendations	69
	RECAPITULATION OF CONCLUSIONS	71
	RECAPITULATION OF RECOMMENDATIONS	73

	Page
APPENDIXES	
I Handbook of Instruction for Aircraft Designers (Excerpts)	77
II Applicable Military Specifications	79
III Crash Safety Criteria	81
DISTRIBUTION LIST	87

INDEX OF ILLUSTRATIONS

- | | | |
|--------|----|--|
| Figure | 1 | The YHC-1B Mockup |
| Figure | 2 | YHC-1B Configuration |
| Figure | 3 | Airframe Sections |
| Figure | 4 | Left front view showing access doors to electronic installation area and jettisonable exit for copilot |
| Figure | 5 | Main landing gear and fuel cell area |
| Figure | 6 | Landing gear and fuel cell |
| Figure | 7 | Aft fuselage pylon |
| Figure | 8 | Cargo door retracted |
| Figure | 9 | Fuel cell aft bulkhead |
| Figure | 10 | Aft landing gear |
| Figure | 11 | View of right front |
| Figure | 12 | Entrance to flight control area |
| Figure | 13 | Flight control area |
| Figure | 14 | Copilot's seat |
| Figure | 15 | Copilot's seat |
| Figure | 16 | Pilot's seat |
| Figure | 17 | Pilot's seat, underside |
| Figure | 18 | Copilot's seat tilt adjustment |
| Figure | 19 | Pilot seat showing safety belt and shoulder harness |

- Figure 20 Pilot in normal seated position
- Figure 21 Lateral displacement of shoulder harness in guide
- Figure 22 Copilot being thrown sideways
- Figure 23 Pilot's head striking aft bulkhead
- Figure 24 Copilot striking head against aft bulkhead
- Figure 25 Instrument Panel
- Figure 26 Crew chief seat (looking forward)
- Figure 27 Crew chief seat (looking aft)
- Figure 28 Crew chief in normal seated position
- Figure 29 Crew chief striking aft cockpit bulkhead flange
- Figure 30 Crew chief striking head against edge of pilot's seat
- Figure 31 Right side - pilot's environment
- Figure 32 Overhead control console
- Figure 33 Overhead control console
- Figure 34 Radio control console
- Figure 35 Main cabin looking forward
- Figure 36 Main cabin door
- Figure 37 Sketch of troop seat
- Figure 38 Three-man troop seat
- Figure 39 Troop seats folded
- Figure 40 Troop seats installed

- Figure 41 Troop seat being installed
- Figure 42 Seat pan material being installed
- Figure 43 "O" rings
- Figure 44 Safety belts
- Figure 45 Lock-pin hole and method of attaching beam to rail
- Figure 46 Occupant seated on troop seat
- Figure 47 Occupant seated on troop seat
- Figure 48 Litter installation
- Figure 49 Litter post with brackets
- Figure 50 Litter strap
- Figure 51 Litter strap floor anchorage
- Figure 52 Emergency exit window
- Figure 53 Landing ramp cargo door
- Figure 54 "Cut Here" markings on right side window
- Figure 55 Hoist/rescue hatch
- Figure 56 Cargo door
- Figure 57 Cargo door in closed position
- Figure 58 Front left cabin emergency exit
- Figure 59 Top of cabin
- Figure 60 Recessed hoist operating controls

- Figure 61 Cargo tie-down rings
- Figure 62 Pilot's seat failure in an H-21 accident
- Figure 63 Copilot's seat failure, H-21 accident
- Figure 64 Support member that produced fatal injury,
H-21 accident
- Figure 65 Troop seat failures, H-21 accident
- Figure 66 Seat structure, belt, anchorage and other failures,
H-21 accident
- Figure 67 Troop seat damage, H-21 accident

FOREWORD

In its efforts to determine the crash survival aspects of aircraft accidents, Aviation Crash Injury Research (AvCIR), a division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft occupants. The same criteria are also used to evaluate the crash safety features of mock-ups and prototypes.

Following is a brief description of these criteria:

1. Crashworthiness: The ability of basic aircraft structure to provide protection to occupants during survivable impact conditions.
2. Tie-down chain: All the components of the occupant seating and restraint system including the seat belt, the shoulder harness, the seat structure, the floor, and all related anchorages.
3. Occupant environment: The injury potential of all objects and structure within the occupant's striking range.
4. Transmission of crash force: The manner in which crash forces are transmitted (magnified or attenuated) by intervening structure to the occupants.
5. Post-crash factors: Post-crash fire, inadequate emergency exits, poor ditching characteristics, etc.

For a more elaborate discussion of crash safety criteria, reference is made to Appendix III.

BACKGROUND

A crash injury evaluation of the Mock-up of the YHC-1B "Chinook" helicopter was conducted by AvCIR, a division of the Flight Safety Foundation, on 27 January 1960 at the request of the U. S. Army Transportation Research Command (TRECOM).

The evaluation was accomplished during the Mock-up Review Board Proceedings which were held at the Vertol Corporation, Morton, Pennsylvania.

The purpose of the evaluation was to:

1. Evaluate the overall crashworthiness of the basic aircraft structure.
2. Determine the existence, if any, of features which could lead to unnecessary exposure of crew members and passengers to serious or fatal injury in the event of a survivable-type accident.
3. Make recommendations for remedial action in the areas where deficiencies exist in order to improve the overall crash safety aspects of the aircraft.

The above work was accomplished through a detailed crash injury evaluation of the entire aircraft, its components and equipment, and supported by discussions with members of the Vertol engineering staff and reference to technical manuals and military specifications.

This is the final report on the crash injury evaluation.

* Additional copies of the photographs used in this report may be obtained by forwarding request to USA, TRECOM, Fort Eustis, Virginia, Attn: RCO.

SUMMARY

The U. S. Army model YHC-1B helicopter mockup was presented for a board review by the Vertol Aircraft Corporation, Morton, Pennsylvania, January 27, 1960.

Aviation Crash Injury Research participated in the mockup review independently from the mockup board, evaluating the aircraft from a crash survival point of view. As a result of the evaluation, which was based in part on previous accident experience, it was concluded that a number of desirable crash safety features exist:

1. The crew compartment and main cabin generally appear to offer crashworthy features free from the great number of protruding, injurious components usually found in earlier model Army troop-carrying helicopters.
2. The YHC-1B presents a good cockpit arrangement with the instrument panel mounted low and out of striking range for an adequately restrained pilot and copilot.
3. Objects such as overhead consoles, lights, and motors are installed and mounted in a recessed manner thereby removing them from striking range of the pilot and copilot.
4. Provisions for emergency exits in the crew compartment are adequate.

The evaluation also revealed a number of crash safety deficiencies existing in troop seats, litter installations, and emergency escape facilities. Certain injurious environmental factors were also revealed in the main cabin. In addition, certain military specifications governing the design and strength of various components such as seats, litters, etc. appear to be deficient in that minimum requirements specified are inadequate and incompatible with today's concept of magnitudes, directions, and time exposures of crash forces within survivable limits.

Based on the data and analyses presented in this evaluation, several recommendations are made concerning the flight control area, the main cabin, the airframe itself, and certain specifications.

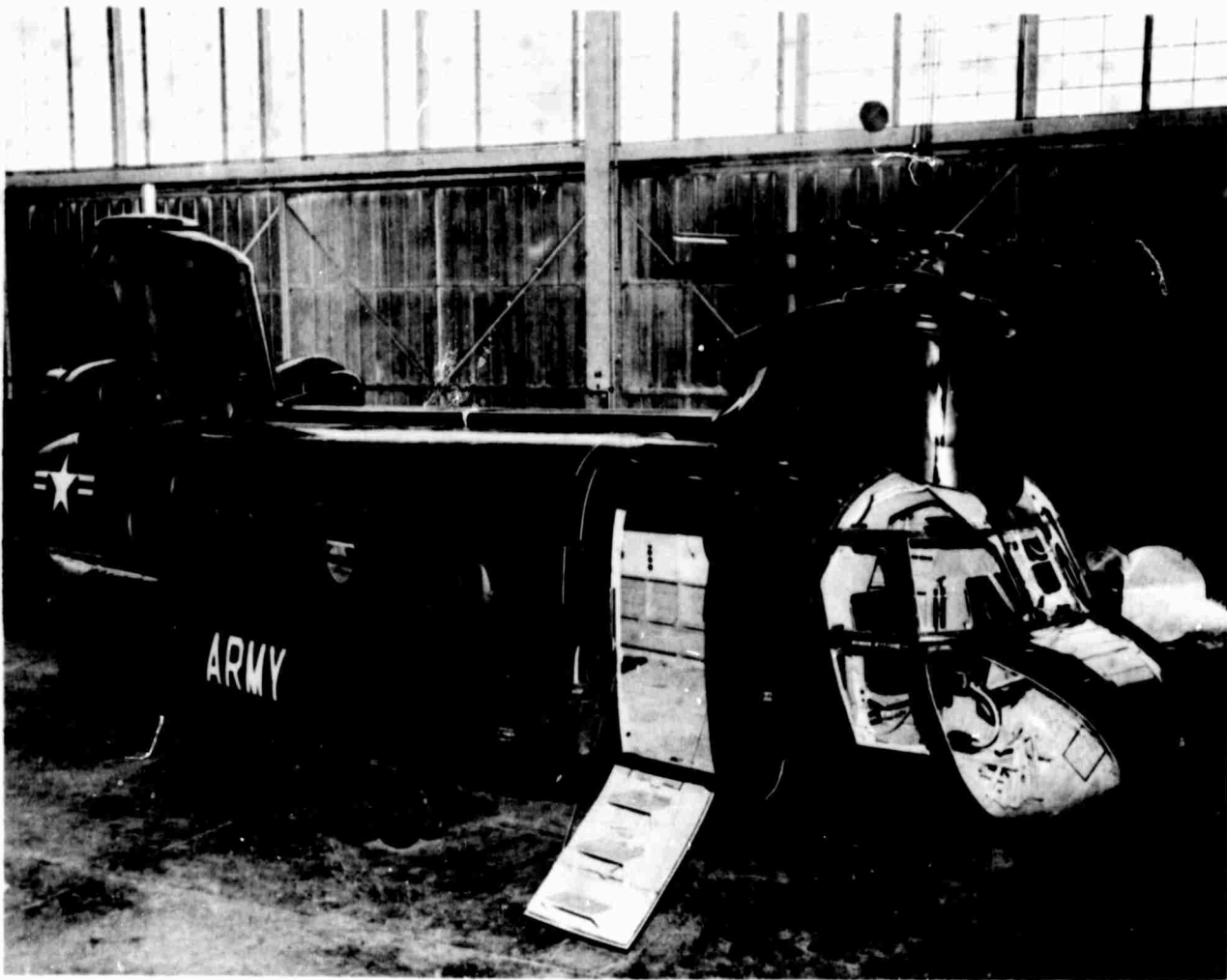


Figure 1. The YHC-1B Mockup.

DESCRIPTION OF AIRCRAFT

The YHC-1B is a tandem-rotor helicopter, powered by two Lycoming YT 55-L-5 turbine engines of 1,940 horsepower each. The helicopter is designed for a cruise speed of 130 knots. Its gross weight varies from 23,500 to 33,000 pounds, depending upon the mission.

The YHC-1B helicopter is designed to increase the mobility of the Army and will be used for the transportation of personnel, weapons, and cargo in both combat and rear areas.

The helicopter is designed to carry a crew of 3 and has accommodations for 33 fully equipped combat troops or 27 paratroopers. The cargo compartment also has provisions for the installation of 24 litters along each cabin wall and 2 one-man troop seats for medical attendants.

Some of the major design features of the aircraft include dual flight stability systems including the Signal Corps' universal automatic flight control system and the Vertol-developed stability augmentation system; a rear loading ramp operable in flight; a retractable winch for loading and unloading cargo and for rescue operations; and emergency water-landing capability with design provisions incorporated for full amphibious operations.

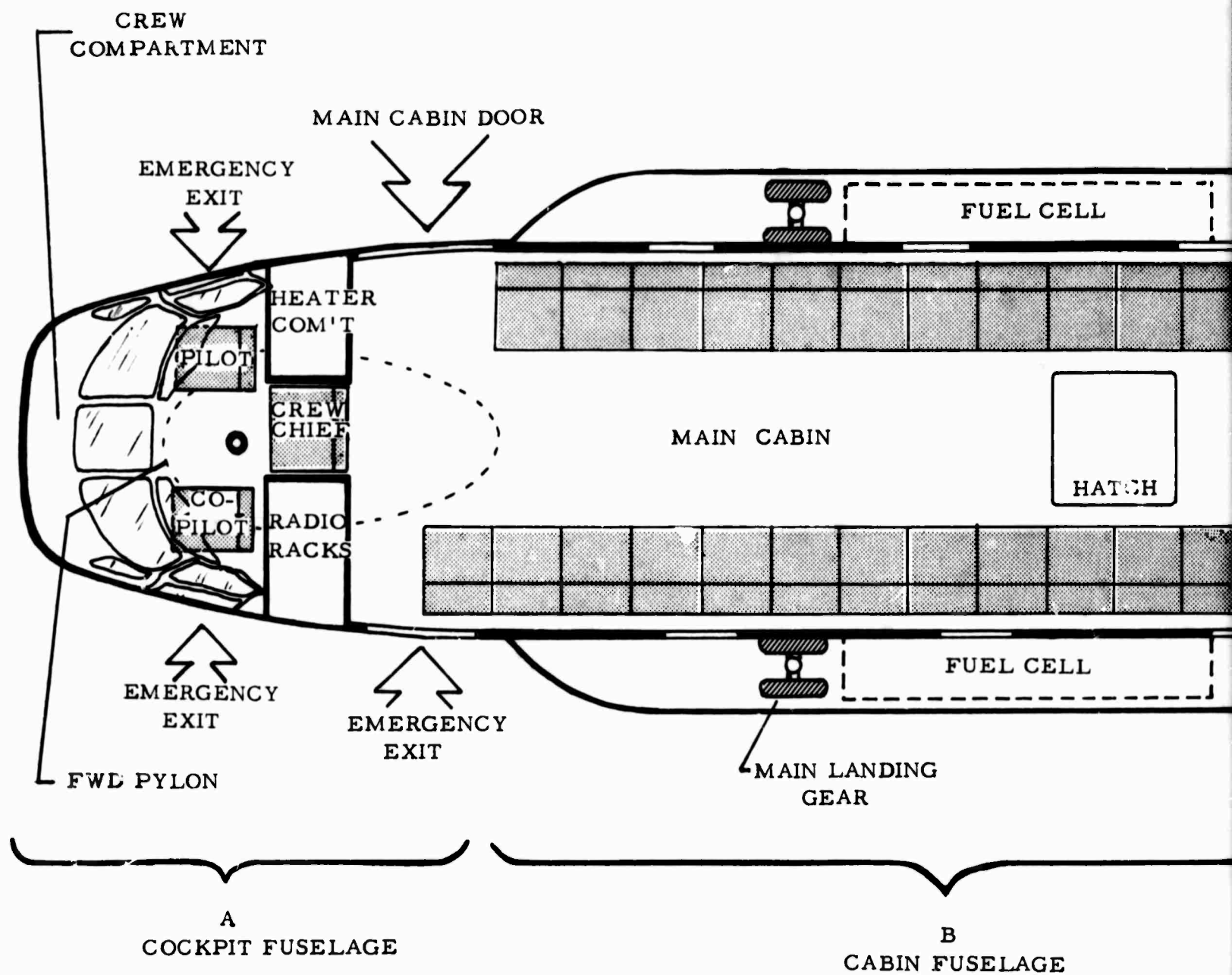
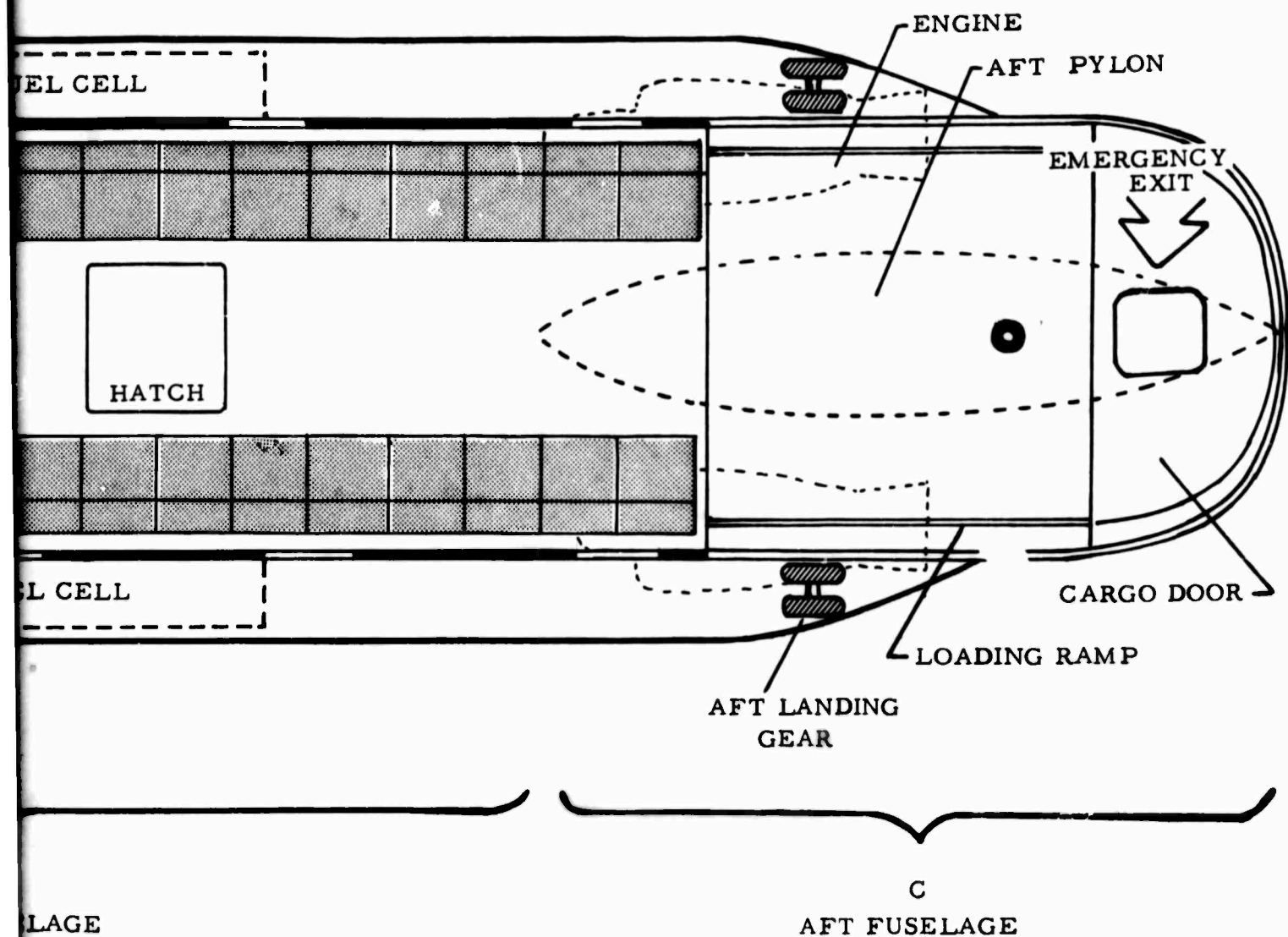


FIGURE 2. YHC-1B Configuration



Configuration

B

EVALUATION OF BASIC AIRFRAME

GENERAL DISCUSSION

The major components of the YHC-1B airframe consist of: (a) cockpit fuselage, (b) cabin fuselage, and (c) aft fuselage (Figure 2). The cockpit fuselage, in which the flight control area is located, supports the forward pylon, transmission, and rotor system. The cabin fuselage houses the major portion of the passenger/cargo area. The aft fuselage, containing the cargo door and ramp, supports the rear pylon, combining gear box, transmission, and aft rotor system. This section also supports the two turbine engines. The two rotor systems are interconnected by a shaft which passes through a tunnel in the roof structure. The three major components of the aircraft are shown in Figure 3.

Each of these major components is discussed separately below, followed by conclusions and recommendations.

COCKPIT FUSELAGE

The cockpit fuselage (Figures 2 and 3) is completely fabricated and assembled prior to splicing to the cabin fuselage section. This forward section serves as the crew compartment and supports the forward transmission and rotor assembly; it also includes the left front window and the main cabin exit on the right (Figure 2).

Before analyzing the supporting structure for the forward transmission and rotor system (shown in Figure 3) to determine its capability for supporting these components during a crash, reference should be made to excerpts from Military Specifications MIL-T-8679, Test Requirements, Ground, Helicopter; and MIL-S-8698 (ASG), Structural Design Requirements, Helicopter (quoted in Appendix II).

Specification MIL-S-8698 (ASG), paragraph 3.4.7, provides for sufficient strength of such items as transmissions and their carry-through structure to prevent failure which would result in injury to personnel. This specification further provides that the ultimate inertia load factors shall be those specified by the procuring activity.

It is assumed that careful engineering consideration has been given to the strength of the supporting structures for the forward

Section I

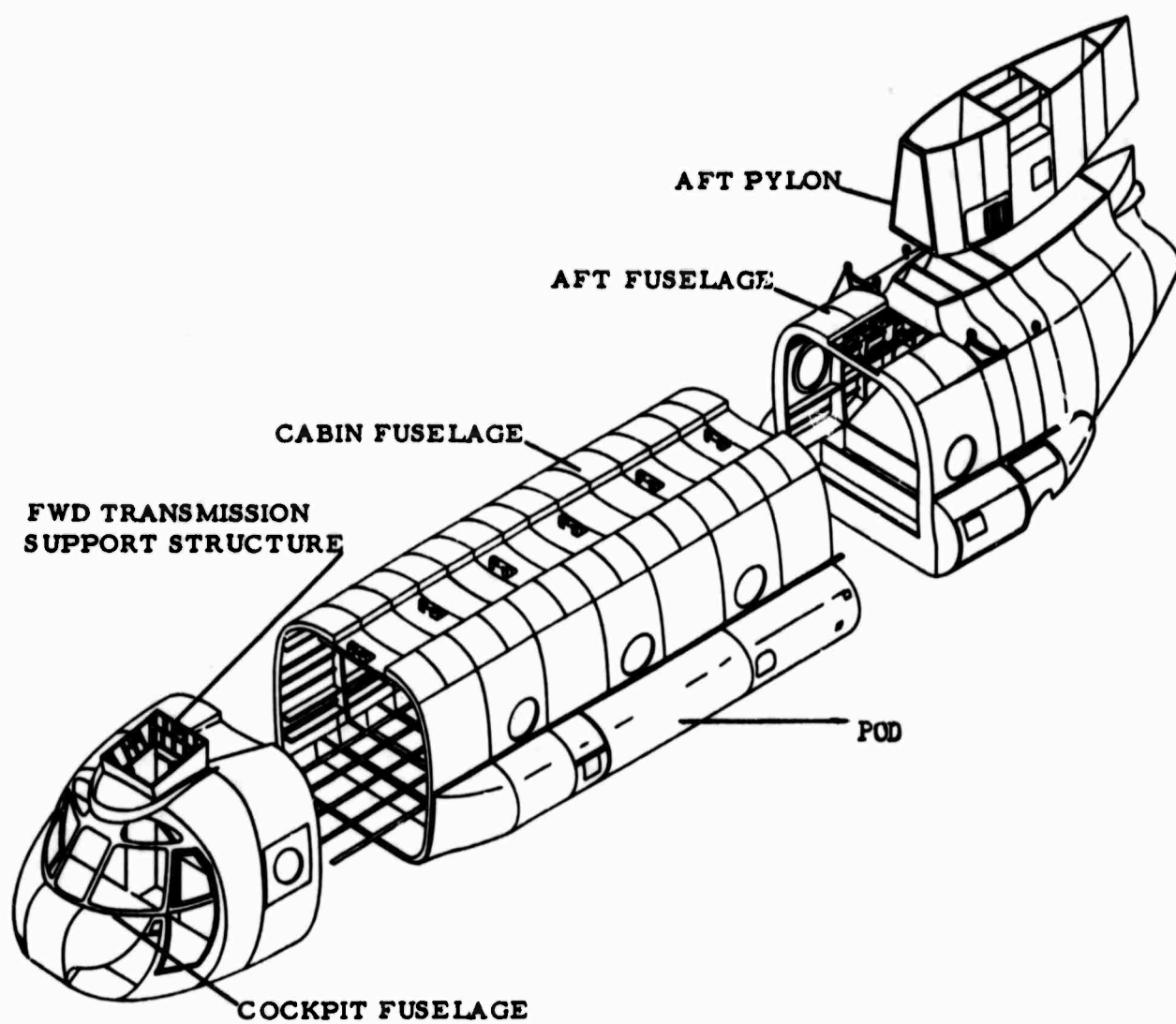


Figure 3. Airframe Sections.

Section I

transmission and rotor assembly to withstand failure under flight load and landing load conditions. However, there is no basis to judge whether these supporting structures actually are stressed sufficiently to prevent the displacement of the transmission and rotor assembly downward into the occupied crew compartment area under survivable crash force conditions.

Although the cockpit fuselage appears to offer a crashworthy structure, or container, for the crew, a thorough analysis and, if necessary, sufficient dynamic tests should be conducted to ascertain whether the forward transmission and rotor assembly will not displace into the crew compartment area under survivable crash force conditions.

CABIN FUSELAGE

The cabin fuselage (Figures 2 and 3) is composed of four panels: the crown, the left side, the right side, and the bottom. The lower section, when covered by the extruded magnesium cargo floor, forms a series of water-tight compartments. The bottom skin and cargo floor are sealed for emergency water landings.

The pods located on each side of the cabin fuselage contain the fuel cells, both main landing gear and the electrical distribution centers. The pods are constructed of metal honeycomb, sealed and compartmented, to provide additional stability and buoyancy for emergency water landings.

The design of the main cabin fuselage appears to be adequate from a crashworthy point of view. It provides for a considerable amount of crushable area in the form of water-tight compartments under the cabin floor. This feature should absorb a considerable amount of the impact energy and reduce the forces (vertical) transmitted to the occupants of the main cabin.

In event of emergency landing on water, the design of the structure under the floor, coupled with the pod design, should provide adequate time for evacuation of the occupants of the cabin.

Section I

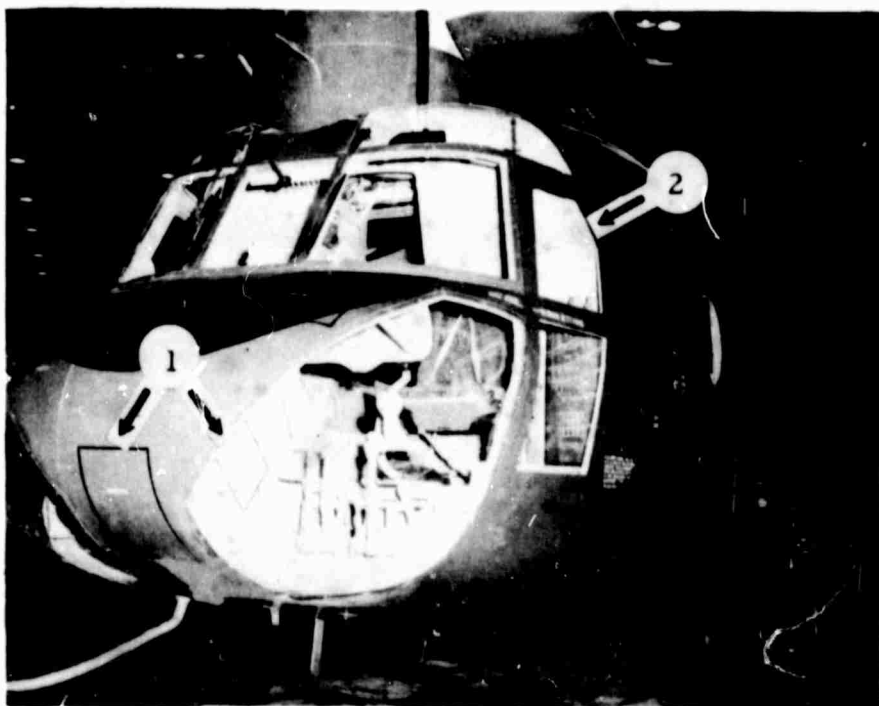


Figure 4. Left front view showing access doors to electronic installation area and jettisonable exit for copilot. Access doors (1); jettisonable exit (2).

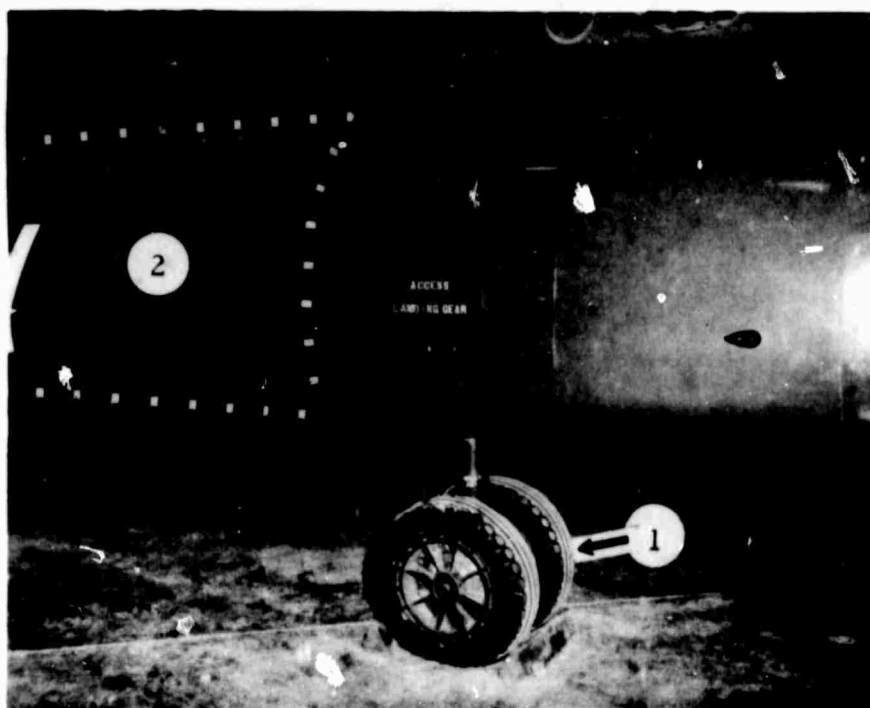


Figure 5. Main landing gear (right) (1); fuel cell area in pod (2).

Section I

Careful attention was given to the location of the main landing gear as shown in Figures 2, 5, and 6. The proximity of this landing gear to the fuel cells creates a potential post-crash fire hazard. Even though impact-resistant fuel cells are to be utilized in this aircraft, it would seem desirable not to expose the fuel cells to more rupture-producing structure than necessary. Accident experience in Army aviation reveals that the majority of the fatalities are the result of post-crash fires, many of which result from hard landings or relatively low magnitude impacts in which the fuel cells were ruptured.

If structural analysis leaves doubt as to the extent to which collapse of the landing gear would affect the fuel cell area, dynamic tests should be conducted on the landing gear fuel cell arrangement.

AFT FUSELAGE

The aft fuselage (Figures 2 and 3) contains the loading ramp, cargo door, and aft landing gear. This section supports the aft pylon which contains the combining gear box, aft rotor system, and the T-55 engines.

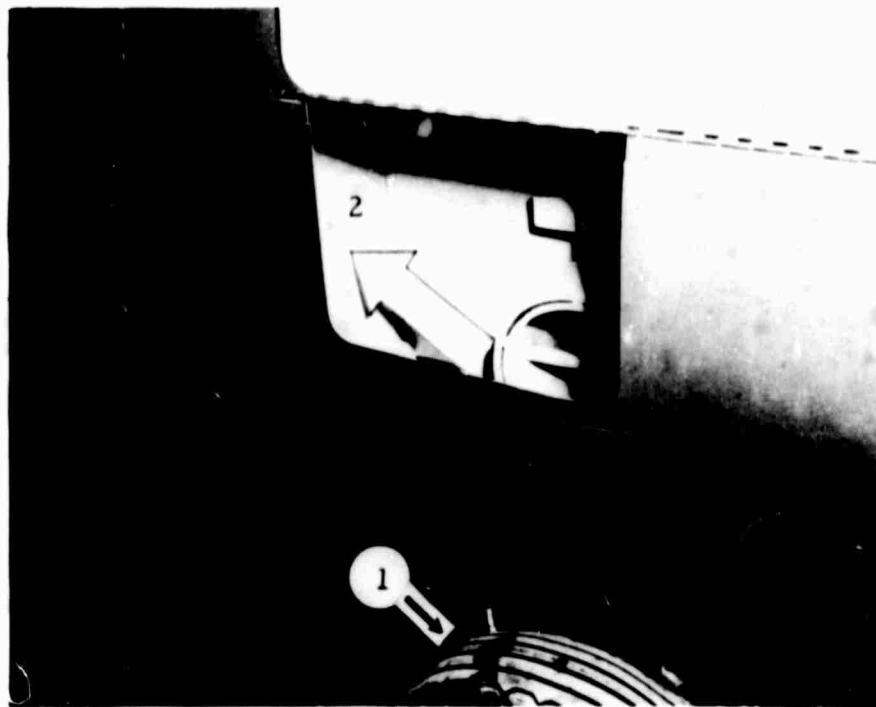


Figure 6. Landing gear (1); fuel cell forward end (2).

Section I

The low drag pods (Figure 7), which were discussed under the main cabin section, extend some distance along the sides of the aft fuselage and house the aft landing gear.



Figure 7. Aft fuselage pylon (1); engine (2); pod (3).

The loading ramp and cargo door (Figure 8) are hydraulically actuated. The cargo door retracts within the loading ramp, and both may be left open in flight to carry out cargo drops or to carry equipment which is longer than the cargo compartment.

The two Lycoming T-55 engines (Figures 7 and 8) are mounted externally on the roof structure of the aft fuselage on either side of the aft pylon.

Section I

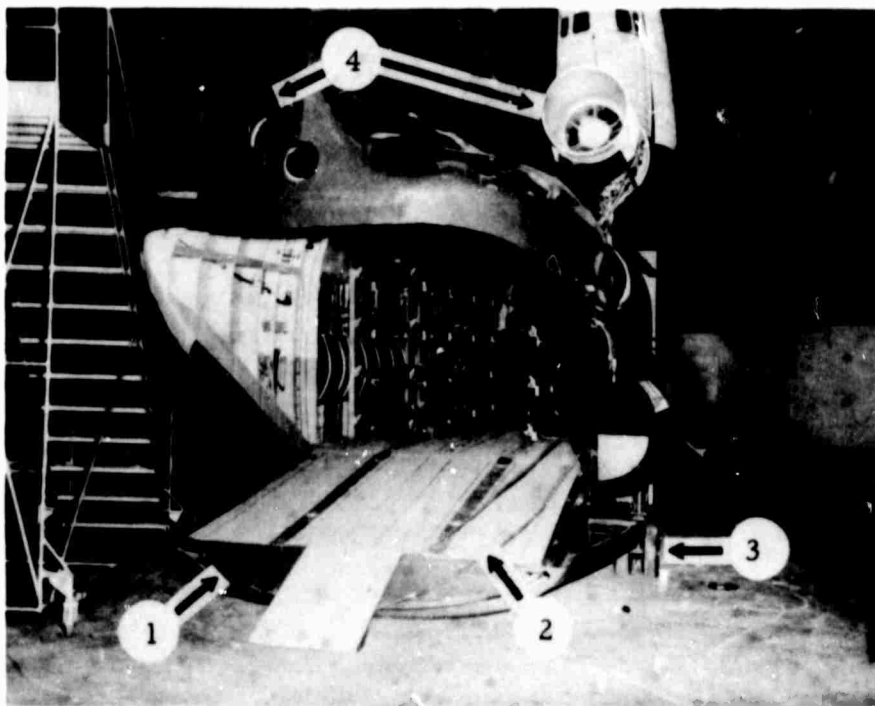


Figure 8. Cargo door retracted (1), ramp open (2), aft landing gear (3), Lycoming T-55 engines (4).

The main pressure fuel lines from the aft fuel cell bulkhead in the main cabin fuselage is routed through the fuselage pod. This routing is illustrated in Figures 9 and 10.

Note in Figure 10 that the pressure fuel line passes between the fuselage wall and the rear landing gear as it enters the fuselage with very little clearance. Any inward displacement of the aft landing gear during a hard landing or during a crash can easily rupture this fuel line. The line should be routed away from the aft landing gear to eliminate a potential source of fuel line rupture and subsequent post-crash fire.

The aft fuselage appears to be structurally adequate from a crash-worthy point of view, provided the supporting structures for the pylon and the engines have been adequately stressed to prevent their forward and downward deformation into the main cabin area under survivable crash force conditions.

CONCLUSIONS

After examination of the basic airframe of the YHC-1B, it is concluded that:

1. The basic airframe provides a crashworthy structure or capsule for protection of the occupants, provided the overhead structures are adequately stressed.
2. Structural analysis and/or dynamic tests should be conducted on certain elements of the basic airframe structure to assure its crashworthiness and to make certain that post-crash fire hazards are not present.
3. Several modifications should be made to eliminate positive post-crash fire hazards found during the evaluations.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. A thorough analysis and necessary dynamic tests be conducted to ascertain whether the forward and rear transmissions and rotor support assemblies are adequate to prevent displacement of these units into occupied areas under survivable crash conditions.
2. Consideration be given to dynamic testing of the main landing gear, pod, and fuel cell arrangement to determine the capability of the fuel cells to resist rupture under survivable crash force conditions.
3. The support structure for the turbine engines be so designed as to allow the engines to break loose and be thrown clear of the aircraft during a crash.
4. The pressure fuel lines be routed away from the aft landing gear to eliminate a potentially serious fire hazard.

Section II



Figure 9. Fuel cell aft bulkhead (1) in pod; main pressure fuel lines (2).

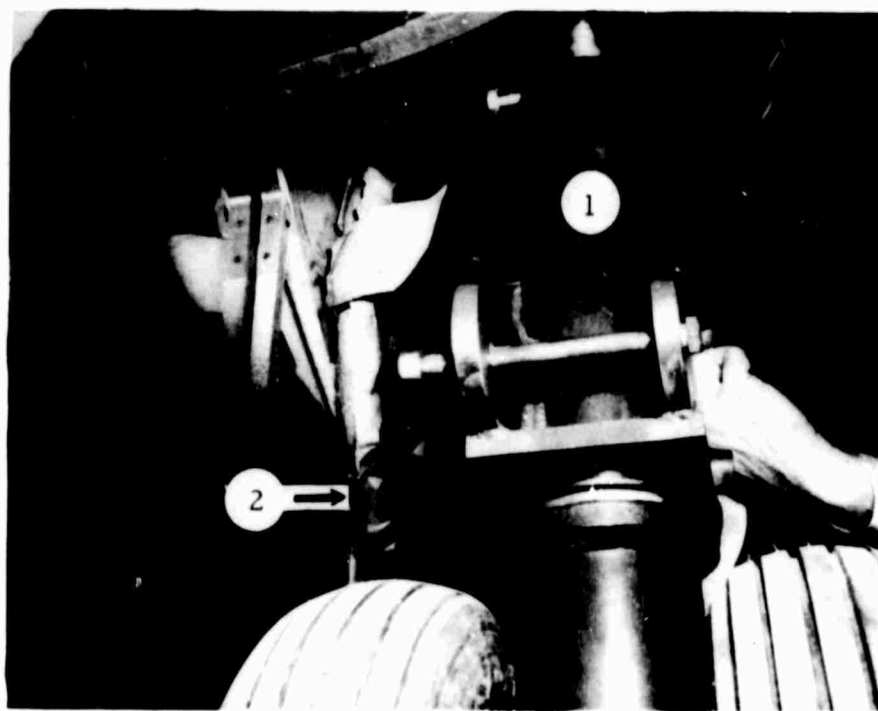


Figure 10. Aft landing gear (1); pressure fuel line (2).

EVALUATION OF CREW COMPARTMENT

GENERAL DISCUSSION

The crew compartment is located in the cockpit fuselage (Figure 2). Maximum visibility is a basic design feature. Two jettisonable emergency escape exits for pilot and copilot are provided.



Figure 11. Right front, showing pilot's jettisonable emergency exit.

Normal entrance and exit to and from the crew compartment are made through the main cabin door, shown in Figure 2, through a passageway between the heater compartment and radio racks (Figure 12). The crew chief's seat is stowed in a folded position against the lower right wall in the passageway when the aircraft is not in flight. The floor level of the crew compartment is two steps up from the main cabin floor level. Figure 13 is a general view of the crew compartment area, looking forward, showing the pilot's seat on the right and the copilot's seat on the left.

Section II

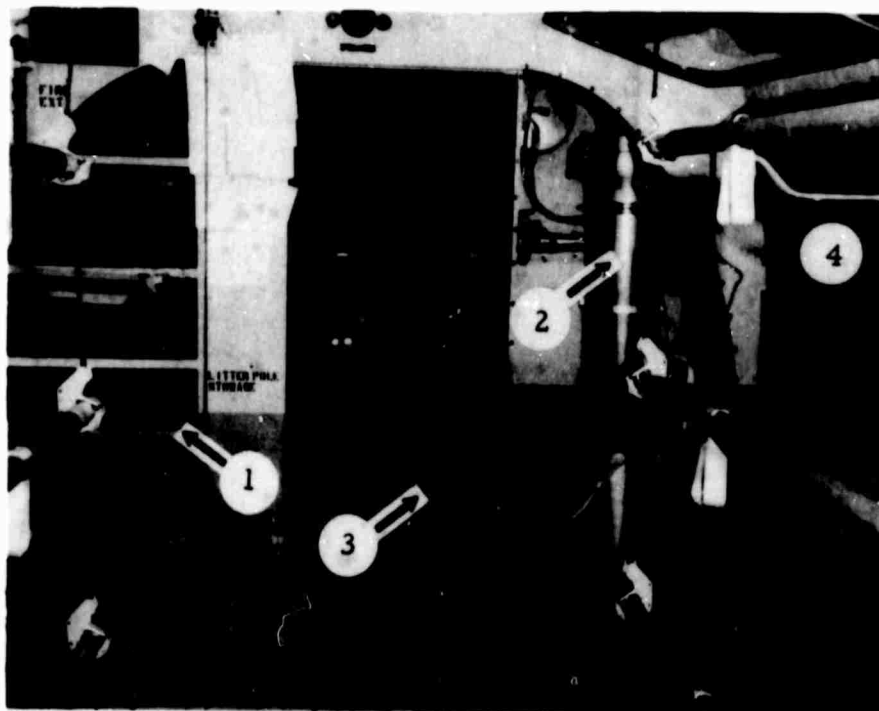


Figure 12. Entrance to flight control area (crew compartment).
Electronic racks (1); heater (2); crew chief/ troop commander seat (3); main cabin door (open) (4).



Figure 13. Flight control area. Pilot seat (1); copilot seat (2).

PILOT'S AND COPILOT'S SEATS

The pilot and copilot seats are identical and interchangeable. All descriptions and comments, therefore, will apply to both seats.

The seat (illustrated in Figures 14 and 15) incorporates a sheet metal back and seat frame. The seat pan is padded with foam rubber and covered with a nylon net material which is fastened to the seat with snap fasteners. The seat is adjustable up, down, fore and aft, and up to 15 degrees of tilt.

It has been designed for a crash landing load factor of 8 G longitudinally, 8 G vertically and 8 G laterally, acting separately. Although no physical tests (static or dynamic) have been conducted on the seat as a whole, at the time of this writing, preliminary stress and load analyses have been made to insure that the 8 G design requirements will be met.



Figure 14. Copilot's seat. Seat pan (1); seat cushion material (2); foam rubber padding (3); seat back (4).

Section II

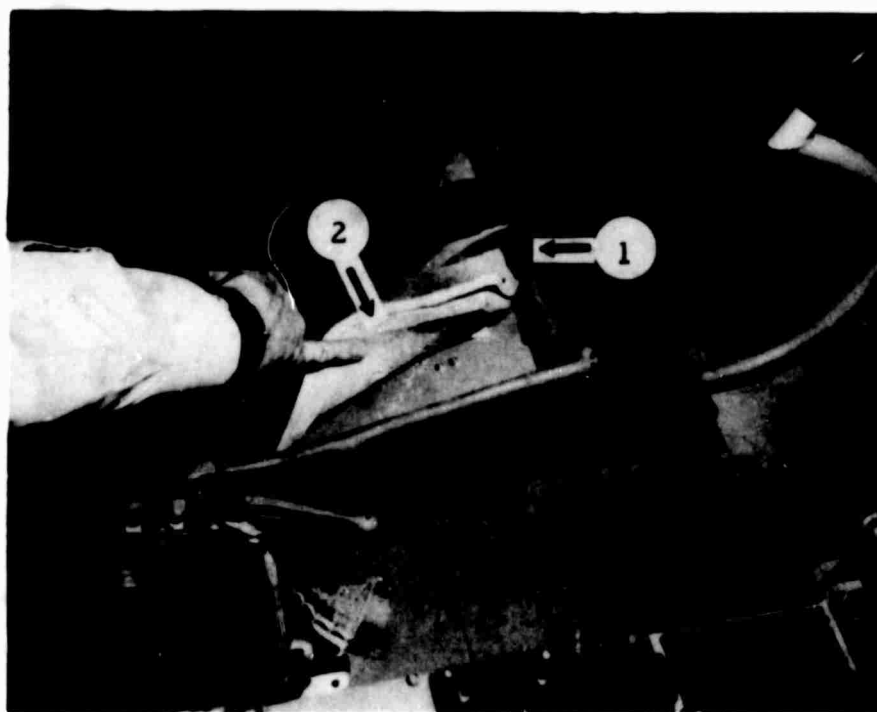


Figure 15. Copilot's seat. Forward edge of seat pan (1) padded with firm density foam rubber; foam rubber seat pan padding (2).

Arrow number 1 in Figure 15 shows the rolled, forward edge of the seat pan. Although padded with a firm density foam rubber, it presents an area for concentration of force to the underside of the thighs during vertical decelerations. This portion of the seat pan should be modified to provide a greater distribution of such forces to a larger area of the thighs.

The nylon net material is fastened to the seat frame (Figure 16). During a crash, all snaps must be fastened to assure symmetrical loading of the seat pan material. Continuous maintenance will be required to insure that all snap fasteners are secured during flight.

Section II

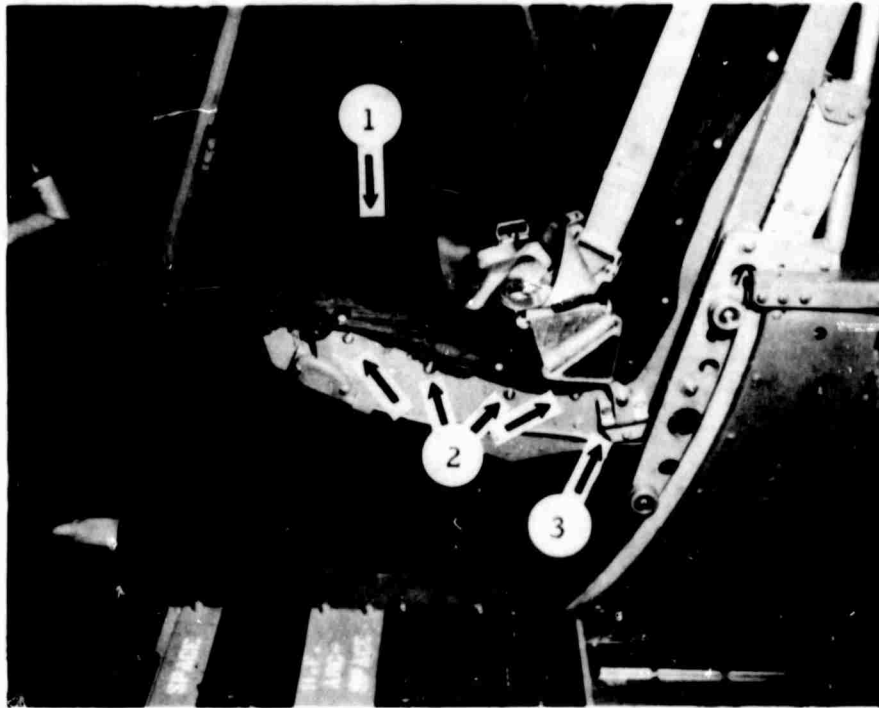


Figure 16. Pilot's seat, showing nylon seat cushion material (1); open snap fasteners (2); and seat belt anchorage (3).

The seats are mounted on seat tracks, as indicated in Figure 17. Examination of the seat tracks revealed no forward stop. It appears that the seats can slide completely off the track in the event of jamming or failure of the manual control stops. Positive stops at the forward end of the tracks should be provided.

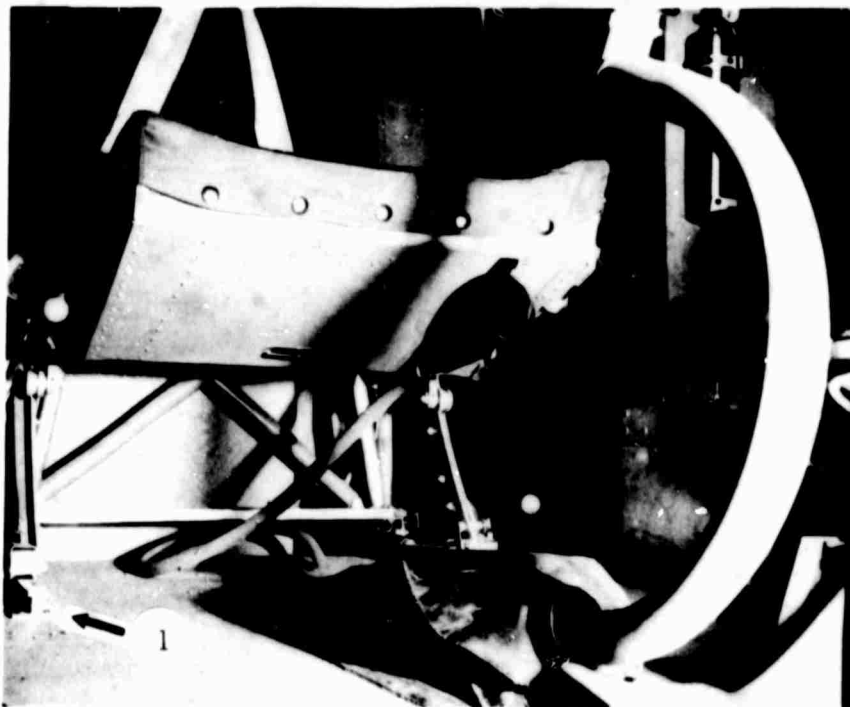


Figure 17. Pilot's seat, underside. Seat track (1).

Section II

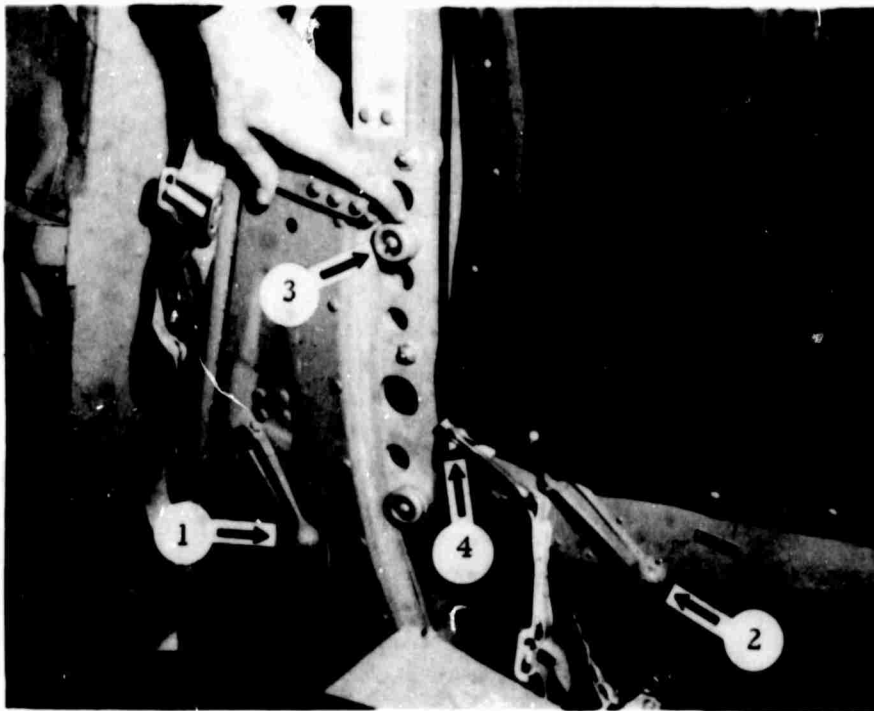


Figure 18. Copilot's seat tilt adjustment control (1); vertical adjustment control (2); tilt adjustment roller and track (3); safety belt anchorage (4).

Figures 18 and 19 illustrate the mechanism for raising, lowering, and tilting the seat. This exposed mechanism is capable of inflicting serious injuries to anyone placing his hand on it while the seat is being adjusted. This mechanism should be covered with a safety shield to prevent contact during seat adjustment.

Figure 19 shows also the safety belt and shoulder harness installation. The seat belt anchorage is located at the lower left corner of the seat pan. The anchorage allows the belt to move inward or outward against the side of the seat pan and to rotate fore and aft in an arc. This form of self-alignment is a desirable feature, preventing anchorage failure due to prying action under side-load conditions.

The shoulder harnesses are attached to inertia reels mounted on the seat backs. Such an arrangement results in impact loading being added to the seat, which tends to overload the seat and cause failure of the seat supporting structure. If the seat does fail, the occupant

Section II

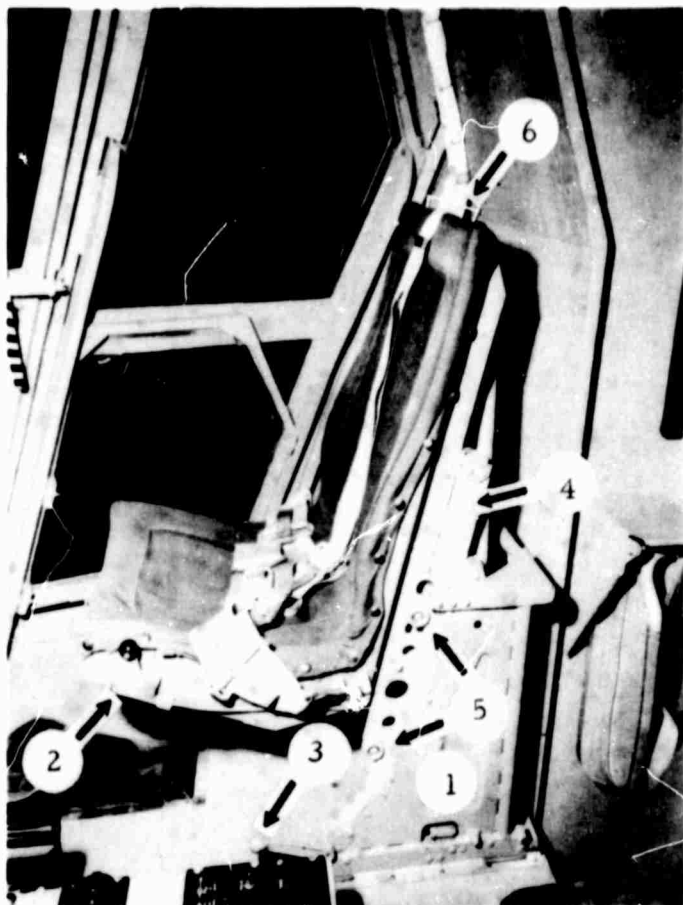


Figure 19. Pilot seat (1) showing supporting structure, safety belt, and shoulder harness installation. Inertia reel manual control (2); fore/aft seat adjustment control handle (3); vertical seat adjustment slide rail (4); seat tilt adjustment rollers (5); eight-inch-wide shoulder harness guide (6) on back of seat top.

restraint system (seat belt and shoulder harness) becomes ineffective and permits the occupant (restrained in his seat) to be thrown in the direction of the crash force. This has been the cause of dangerous and fatal injuries in a number of helicopter accidents. Based upon the foregoing, the inertia reels should be attached to basic aircraft structure to prevent overloading of the seat during crash force decelerations and to provide occupant restraint in event of seat failure.

During the evaluation, it also was noted that the pilot was required to lean slightly forward in his seat in order to reach the controls comfortably, as illustrated in Figure 20. This position requires that the shoulder harness be extended over the seat back a distance of 15 to 18 inches. In the event the pilot (or copilot) is thrown sideways, the extension of the shoulder harness coupled with the unusually wide harness guide (shown in Figure 19) will permit him to strike the door frame and door jettison handle, as illustrated in Figures 21 and 22.

Section II

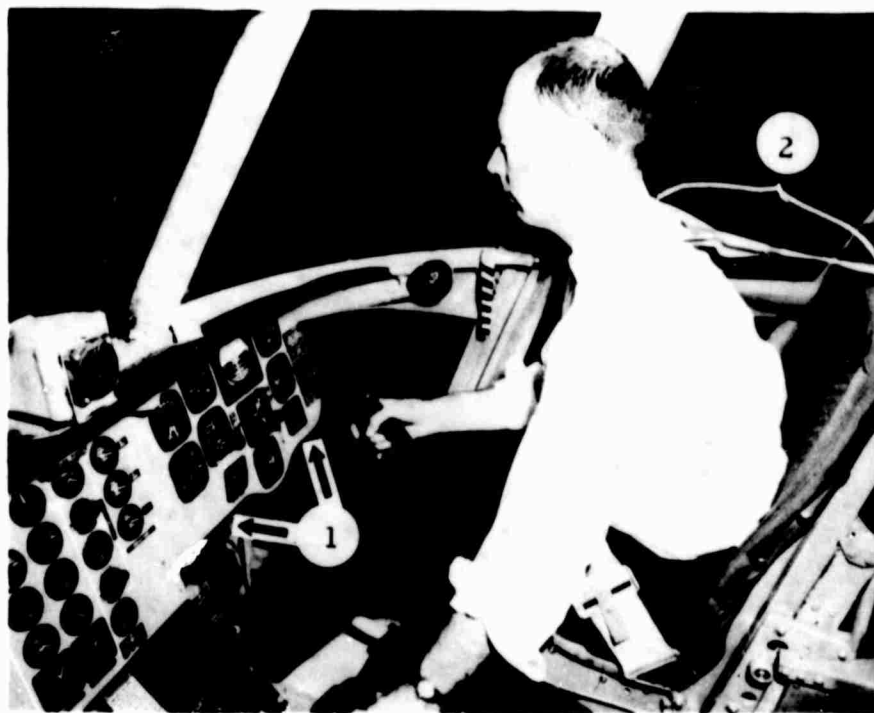


Figure 20. Pilot in normal seated position restrained by safety belt and shoulder harness. Lower edge of instrument panel (1); extended shoulder harness (2).

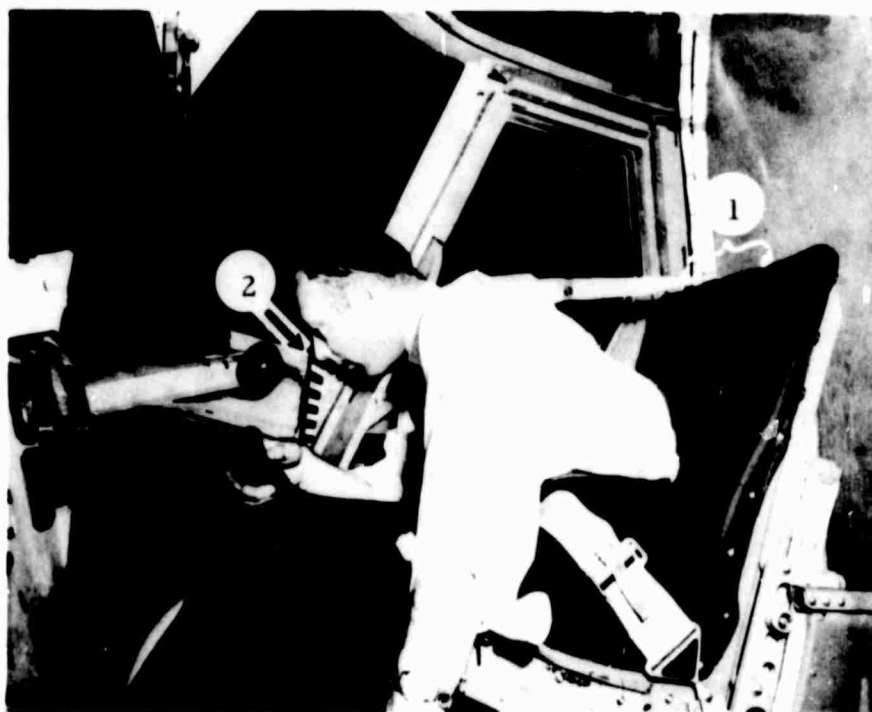


Figure 21. Extent of lateral displacement of shoulder harness due to wide guide (1) allows pilot to strike jettisonable door frame and handle (2).

Section II



Figure 22. Copilot being thrown sideways, head against jettisonable door frame (1); lateral displacement of shoulder harness (2) to the left due to the width of the shoulder harness guide.

The controls should be so located that they can be reached comfortably from a fully upright position; the width of the shoulder harness guide should be reduced to the narrowest possible width; the door frame should be padded with a high energy absorption material; and the door jettison handle should be relocated in a manner to prevent its being struck by either the pilot or copilot.

Section II

Figures 23 and 24 illustrate the manner in which both the pilot and copilot can be injured by striking their heads against the aft bulkhead by rebound during longitudinal decelerations. The bulkheads behind the pilot and copilot seats should be padded with high energy absorption material.

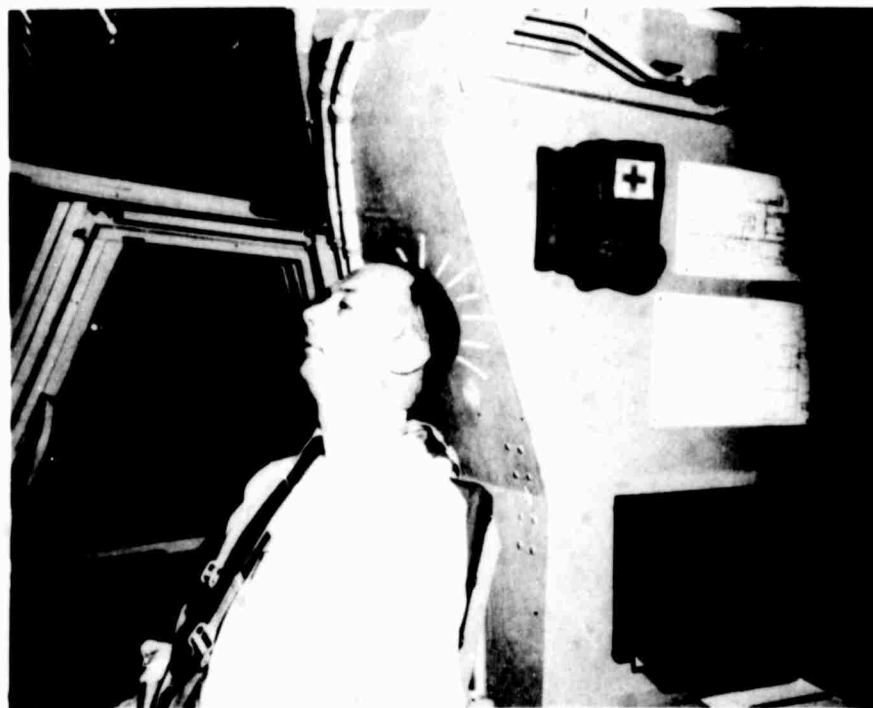


Figure 23. Pilot's head striking aft bulkhead.

The instrument panel, shown in Figure 25, is mounted low and well forward of the pilot and copilot. The panel is beyond striking range of either of the occupants provided they are properly restrained; however, the lower edge of the instrument panel has a sharp edge which can inflict lower extremity injuries when the legs of the pilot and copilot flail upward during longitudinal decelerations. This lower edge should be padded or shielded to reduce possibility of injury.

Section II



Figure 24. Copilot striking head against aft bulkhead (1); fire extinguisher location (2).

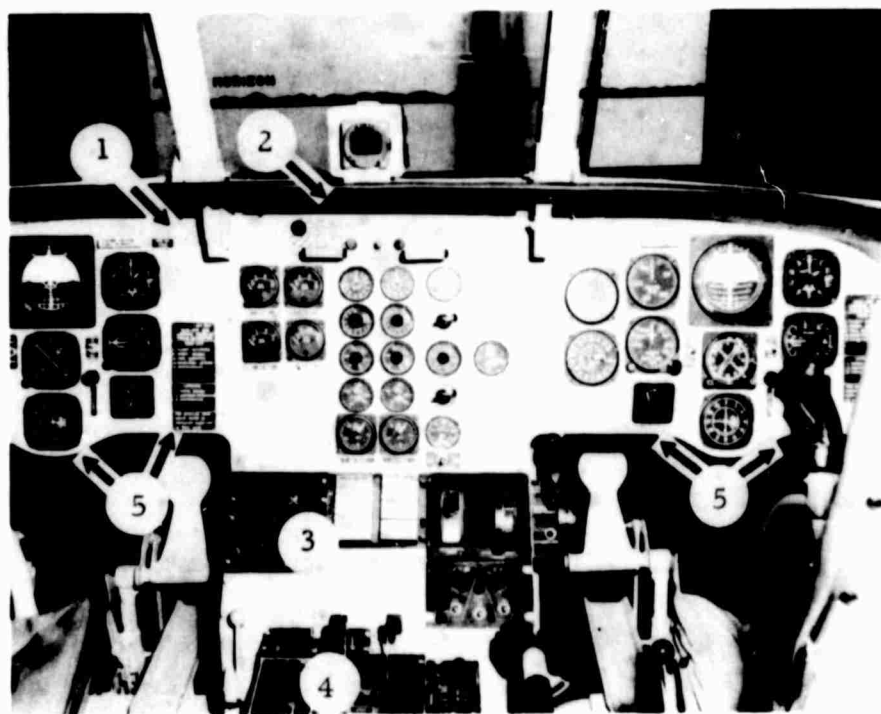


Figure 25. Instrument panel (1); glare shield (2); control pedestal (3); console (4); sharp edge lower instrument panel (5).

CREW CHIEF/TROOP COMMANDER SEAT

This seat is located in the entrance passageway of the crew compartment between the heater compartment and the radio racks (Figure 2). The seat is shown in Figures 26 and 27.

The seat is hinged at two points (Figure 26-3) and is stored against the lower right bulkhead of the passageway. During flight, it is anchored on the left by means of a snap lock (Figure 27-2). The seat back is raised for use as shown in Figure 27.

In the flight position (Figure 27) the occupant is restrained only by a seat belt. The lack of upper torso restraint will permit the occupant to be thrown against various items in his immediate environment during a crash, as illustrated in Figures 28, 29, and 30. The low seat back also could cause a serious back injury in the event this crew chief rebounded during a forward deceleration. This seating arrangement should be carefully studied and every effort made to provide the occupant protection at least equal to that of the pilot and copilot. A higher seat back, some sort of upper torso restraint, and padding of those surfaces within striking range of his head would provide such protection.

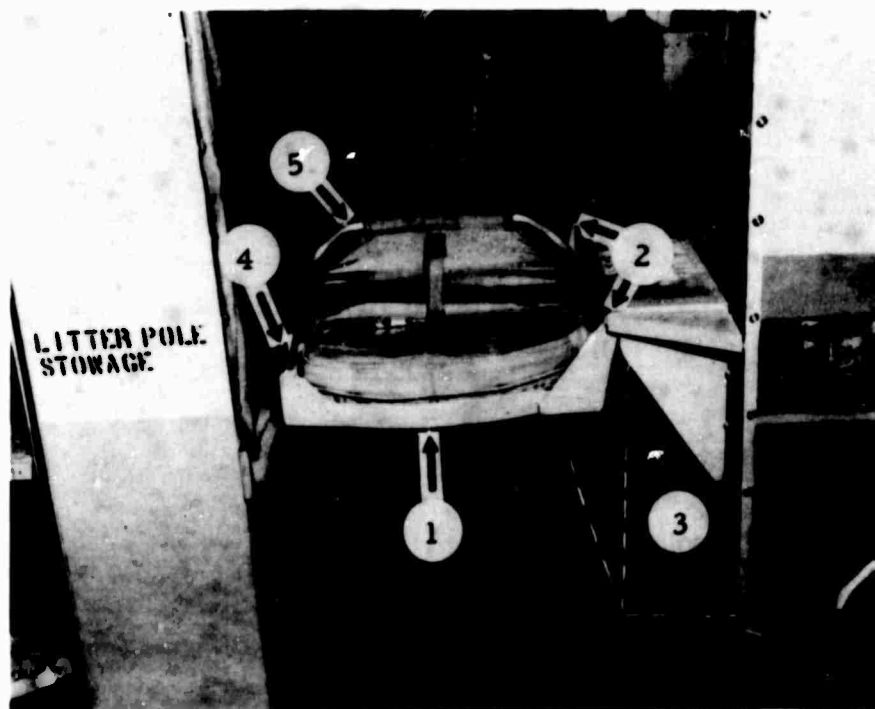


Figure 26. Crew chief/troop commander seat (looking forward) (1); hinge points (2); seat stowage area (3); seat pan snap lock (4); seat back (5).

Section II

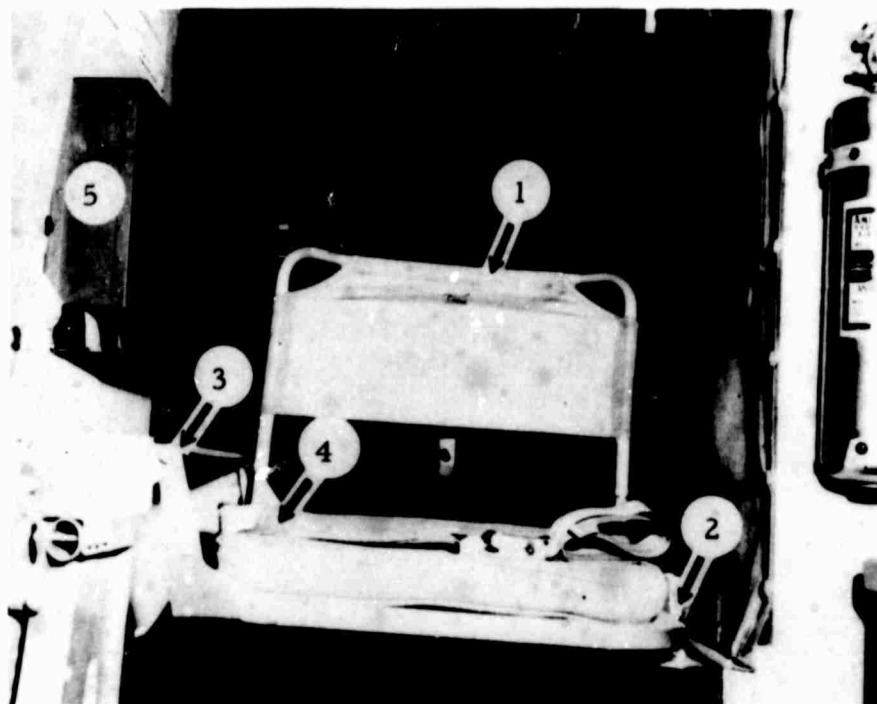


Figure 27. Crew chief/troop commander seat in flight position (looking aft). Seat back (1); seat pan snap lock (2); forward hinge point (3); safety belt (4); map case (5).



Figure 28. Crew chief/troop commander in normal seated position, restrained by safety belt, can strike structures (arrows). Structures behind curtain (1); right passageway bulkhead (2).

Section II



Figure 29. Crew chief/troop commander striking aft cockpit bulkhead flange (1).



Figure 30. Crew chief/troop commander striking head against top left edge of pilot's seat (1). Restraint is by safety belt only.

EMERGENCY EXITS

Two jettisonable emergency exits (Figures 4 and 31) are provided in the cockpit immediately to the right and left of the pilot and copilot. The exits incorporate sliding windows which, when open, offer a means of escape in the event the doors are jammed. The exits can be jettisoned regardless of the position of the windows.

The exits are large enough and are considered adequate and readily accessible for quick emergency escape for all crew members even though the aircraft may roll on its side during an accident, blocking one of the exits.

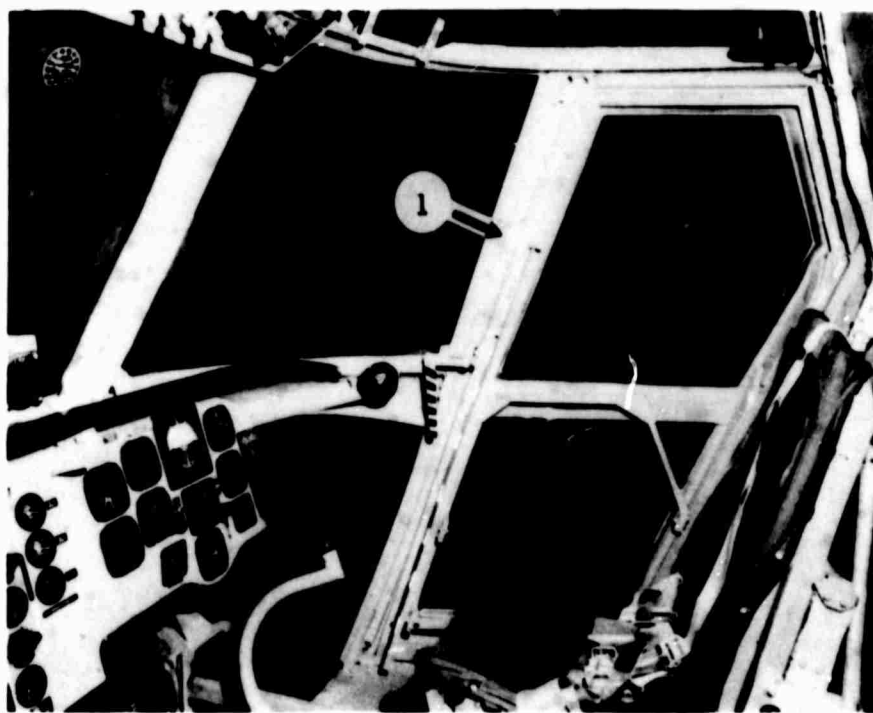


Figure 31. Right side - pilot's environment. Jettisonable emergency door (1).

OTHER EQUIPMENT

Other components in the crew compartment, including the instrument panel, control pedestal, control consoles, glare shield, windshield wiper motor, radio console, etc., are illustrated in Figures 25, 32, 33, and 34. All of these items are considered well placed and/or recessed in a manner that precludes their being struck by crew members who are properly restrained by safety belts and shoulder harnesses (Figure 21).

The evaluation also revealed that no provisions have been made for the installation of an emergency lighting system or a crash axe in the crew compartment. A hand fire extinguisher is adequately installed within reach of the crew members.

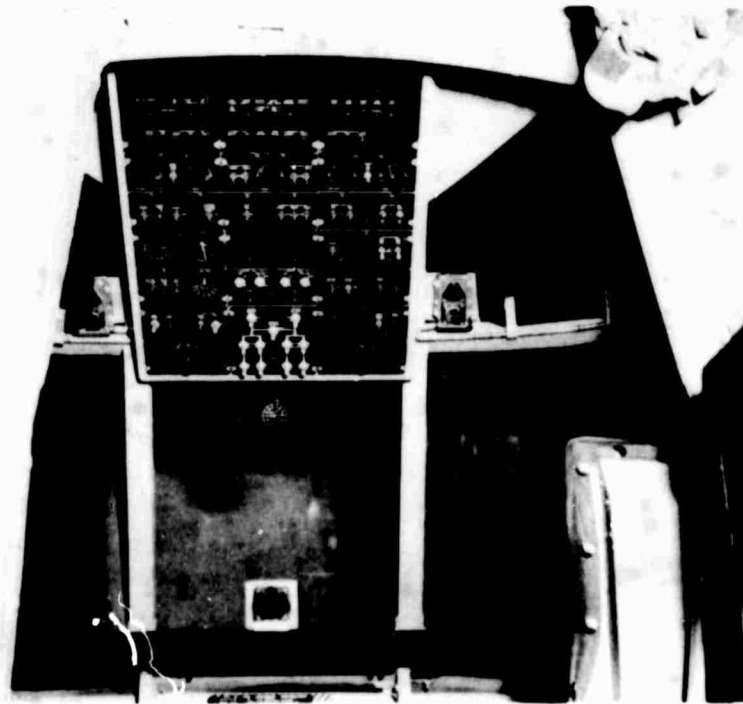


Figure 32. Overhead control console, as viewed from passageway.

Section II

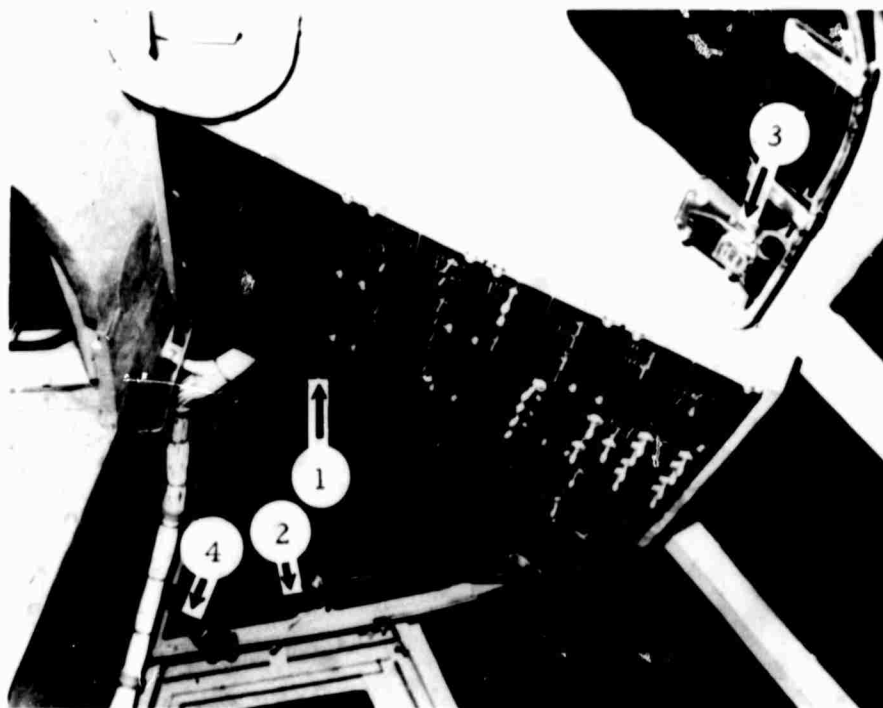


Figure 33. Overhead control console (1); windshield wiper motor (2); wiper gear box (3); fluorescent instrument reading light (4).

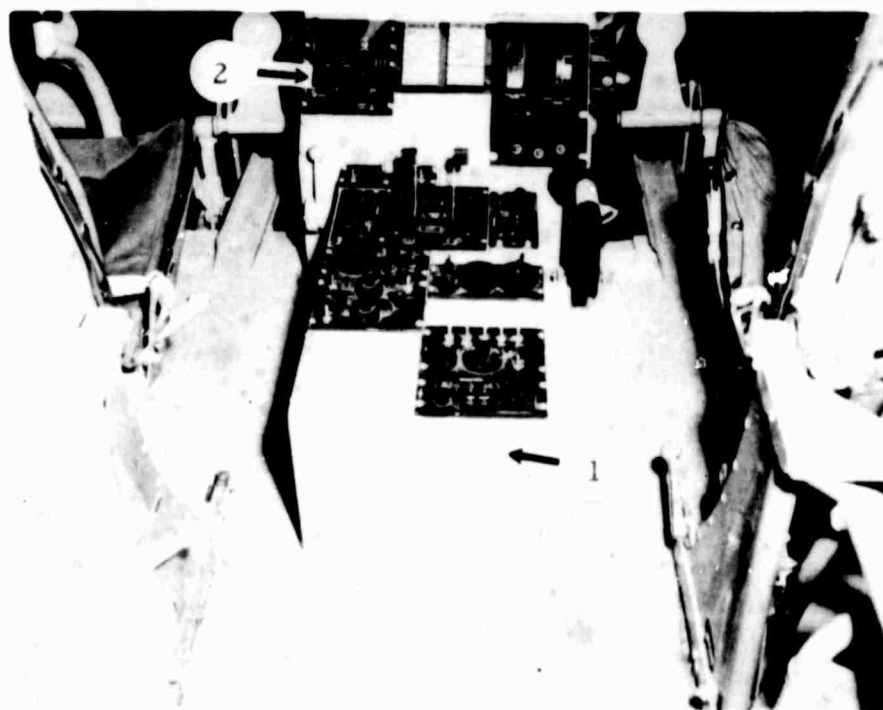


Figure 34. Radio control console (1); control pedestal (2).

CONCLUSIONS

Based upon the foregoing evaluation of the crew compartment, it is concluded that:

1. Emergency exits in the crew compartment are adequate in number, type, and location.
2. Improved crash safety can be provided for the pilot and copilot by certain modification of the seat and shoulder harness installations and by padding areas within their immediate environment.
3. The crew chief/troop commander seat, its environment and restraining system is deficient from a crash safety point of view.
4. Installation of emergency lighting and a crash axe will facilitate emergency escape for the crew.

RECOMMENDATIONS

Based upon the foregoing evaluation of the crew compartment, it is recommended that:

1. The forward edge of the pilot and copilot seat pans be modified to provide for greater distribution (lower p. s. i.) of impact forces over a larger area of the thighs.
2. The forward end of the pilot's and copilot's seat tracks be provided with positive stops.
3. The mechanism for raising, lowering and tilting the pilot's and copilot's seats be covered with a safety shield to prevent inadvertant contact with crew members' hands during seat adjustment.
4. The inertia reels of the pilot's and copilot's seats be attached to basic aircraft structure, rather than to the seats themselves.
5. Instructions be issued to operation, maintenance, and inspection personnel to assure that the nylon seat cover material has all its snap fasteners secured during flight.
6. The location of flight controls (pitch and cyclic controls) be modified in such a manner that they can be manipulated from a normal upright seated position.

Section II

7. The shoulder harness guide be reduced to the narrowest practical width.
8. The vertical support structure (forward edge of jettisonable exit) be padded with a high energy absorption material to prevent head injuries during forcible contact.
9. The jettisonable exit release handle be relocated or recessed in such a manner as to prevent forcible contact by the pilot or copilot and thus prevent inadvertant release during flight operation.
10. The lower edge of the instrument panel be shielded or padded with high energy absorption material.
11. The bulkheads behind the pilot's and copilot's seats be padded with high energy absorption material over the area within striking range of their heads.
12. The crew chief/troop commander's seat and supporting structures be tested dynamically to determine their ability to withstand survivable crash force conditions. (This seat should be subjected to and able to withstand the same G loads as the pilot's and copilot's seats.)
13. The crew chief/troop commander's seat be provided with a higher seat back and some means of upper torso restraint.
14. The structures within striking range of the crew chief/troop commander's head be padded with a high energy absorption material.
15. The crew compartment be provided with emergency lighting, an independent system that can be activated both manually and by impact.
16. The crew compartment be provided with a crash axe, secured in a safe manner and within ready access of the pilot, copilot, and crew chief.

Section III

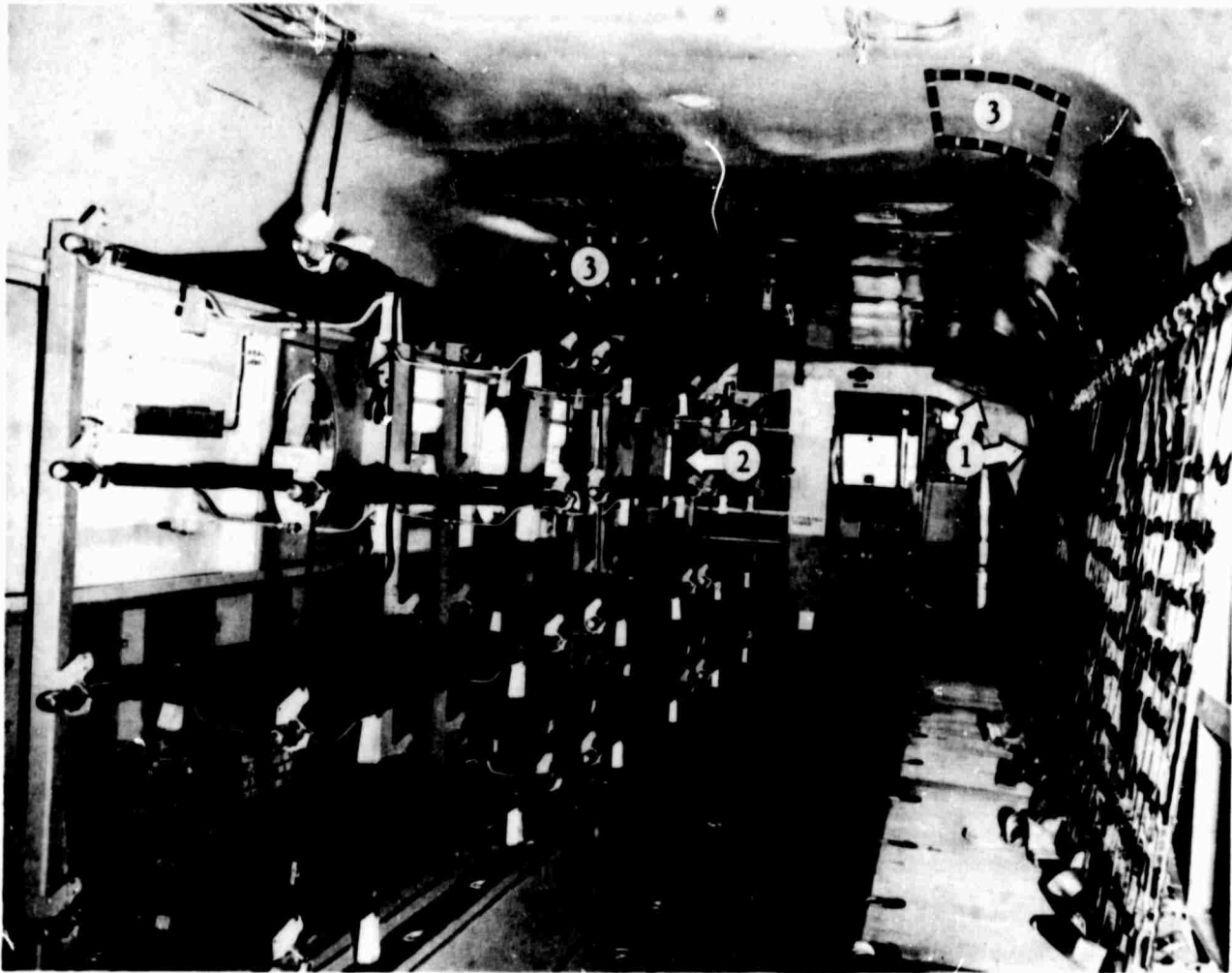


Figure 35. Main cabin of YHC-1B showing litter configuration on left side, troop seating arrangement on right. Main cabin door (1) is at forward end of cabin on right side; emergency exit window (2) is opposite main cabin door; possible location of recommended overhead emergency escape panels (3).

EVALUATION OF THE MAIN CABIN

GENERAL DISCUSSION

The main cabin section of the aircraft is designed to accommodate 33 troops or 24 litters and two attendants. Figure 35 illustrates the main cabin section looking forward, showing the troop seating arrangement on the right and the litter arrangement on the left.

The magnesium cargo floor is designed for a load distribution of 200 pounds per square foot and a concentrated load of 1,000-pounds per wheel in the center section. The outboard portion of the floor, or the treadway, is designed for a 2,500-pound wheel load. The floor contains eighty-three 5,000-pound tie-down fittings and eight 10,000-pound fittings. The loading ramp is also equipped with four 5,000-pound fittings.

Entrance to the main cabin section is through the door at the right forward section of the main cabin, shown in Figure 36, or through the rear end of the fuselage with the loading ramp and cargo door lowered.

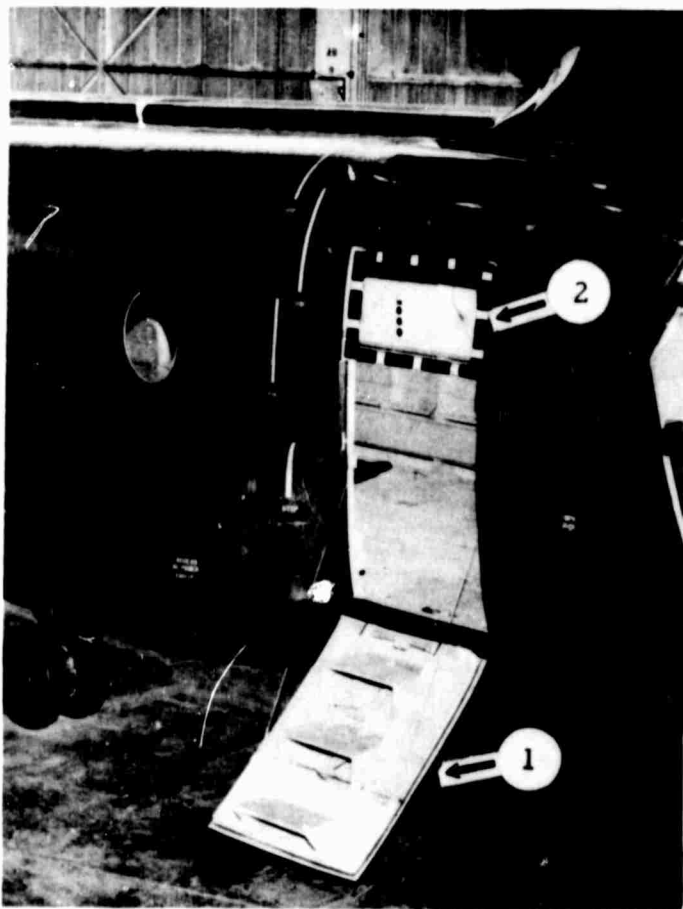


Figure 36. Main cabin door (1) shown in open position; emergency escape panel (2).

The main cabin door is composed of two sections: an upper section (Figure 36-2) which is hinged and may be opened in flight, stowing into the fuselage crown; and a lower section (Figure 36-1) which contains integral steps and is hinged at the cabin floor level to open out and down. This lower section is jettisonable and serves as one of the emergency exits.

TROOP SEATS

The troop seats are arranged along the main cabin walls and face inboard. Ten three-man seats and three one-man seats of the interconnecting, variable width type provide seating for 33 troops with 20 inches of space per man, or 27 paratroops with 24 inches of space per man. The seats are designed to be folded and stowed against the wall.

Figure 37 illustrates the basic components of the troop seat. The upper and rear support beams are drilled at regular intervals to provide for fittings which attach these two support members to the basic aircraft structure. The forward seat support beam is separated from the rear support beam by means of a crosstube which clamps to the two beams. The seat legs, attached to the forward support beams by means of an encircling clamp with a friction lock, anchor to attachment points in the floor.

The seat pan consists of a nylon fabric which is attached to the forward and rear seat support beams, as illustrated in Figure 38. The seat pan (nylon fabric) folds around the rear support beam and is sewn and riveted on the underside, as illustrated in Figure 39-6. The seat pan is attached to the forward seat support beam by use of screws through a reinforcing strip.

The seat back consists of nylon webbing straps which are sewn to the seat pan on the lower end and suspended from the upper seat support beam by the use of clips (Figure 40-3). The seat back is pulled taut by means of adjusters (Figure 40-5).

Section III

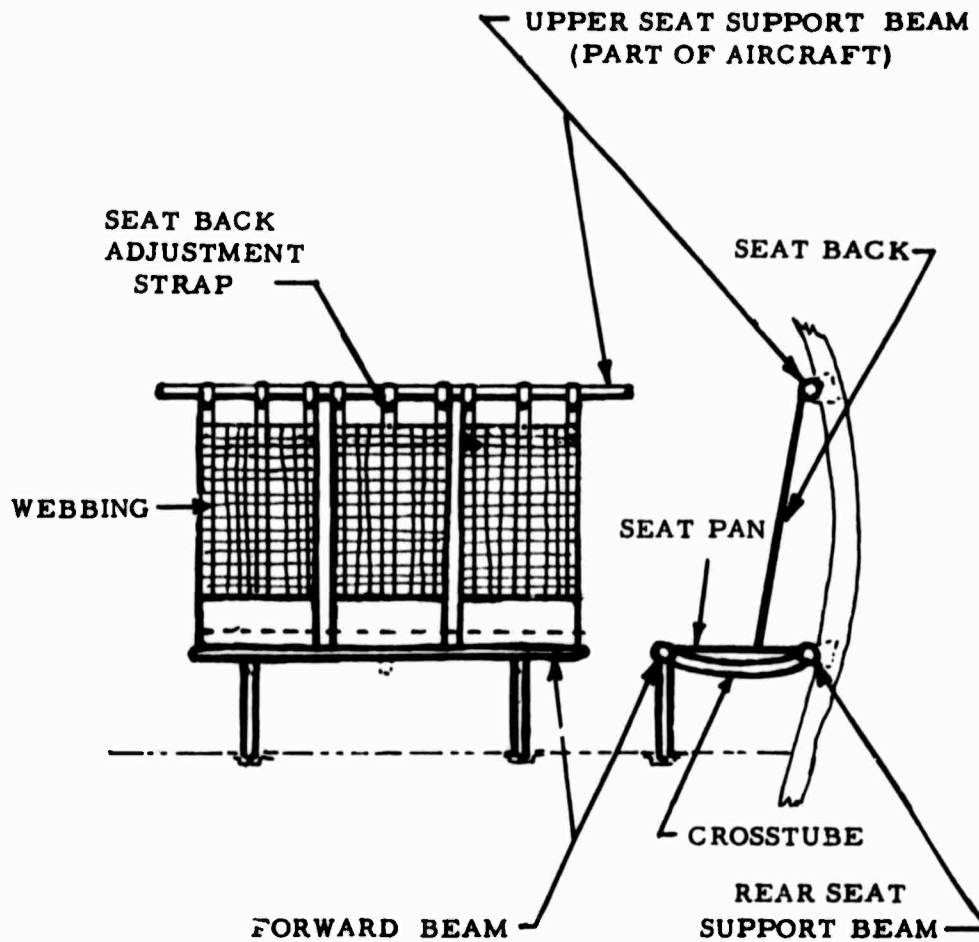


Figure 37. Troop seat (three-man, type F-2) design.

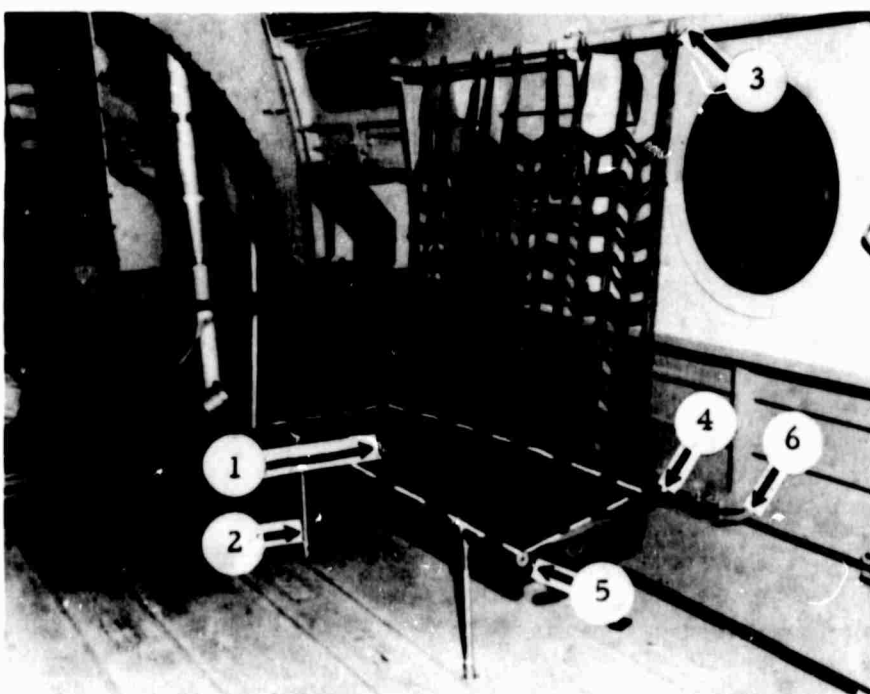


Figure 38. Three-man troop seat. Seat pan (1); seat leg (2); upper beam (3); rear beam (4); forward beam (5); seat support rail (6).

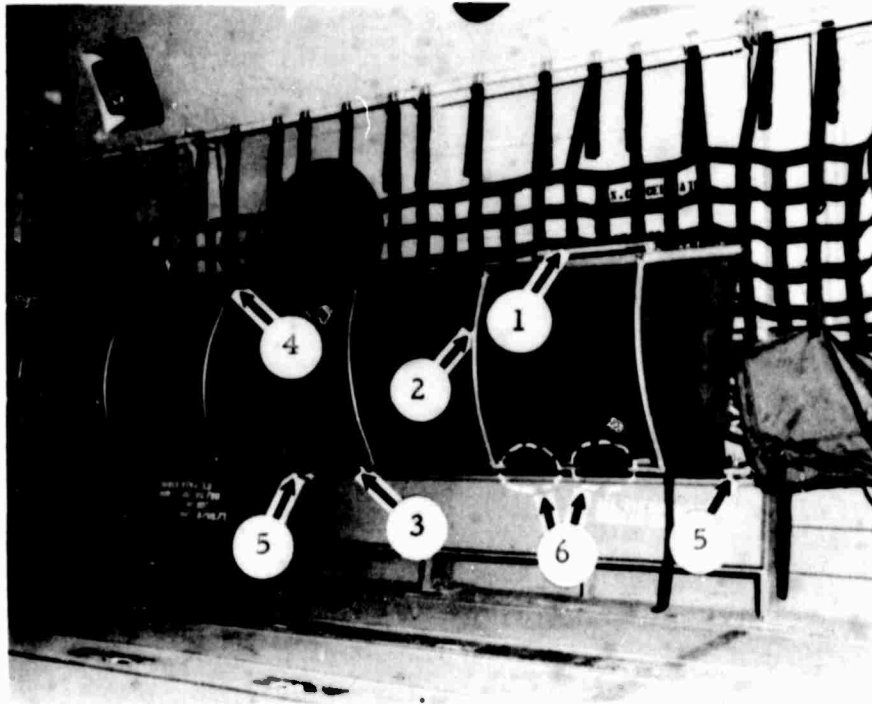


Figure 39. Troop seats folded in stored position. Seat leg (1); cross-tube (2); rear beam (3); forward beam (4); rear beam anchorages (5); seat pan nylon material attachment to rear beam (6).

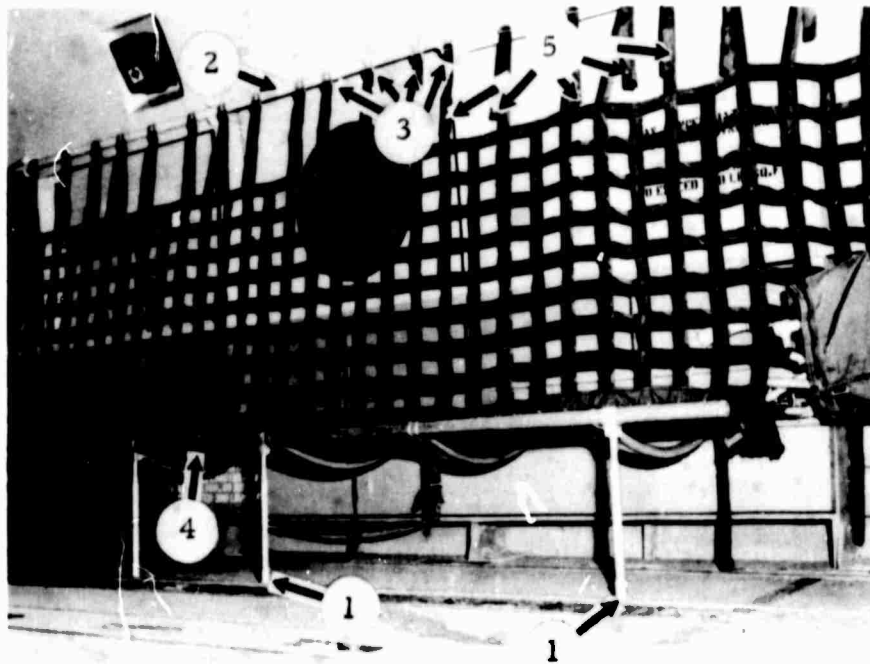


Figure 40. Troop seats installed. Seat leg anchorage (1); upper beam (2); seat back clips (3); seat beam locks to adjacent forward seat beam (4); seat back strap adjusters (5).

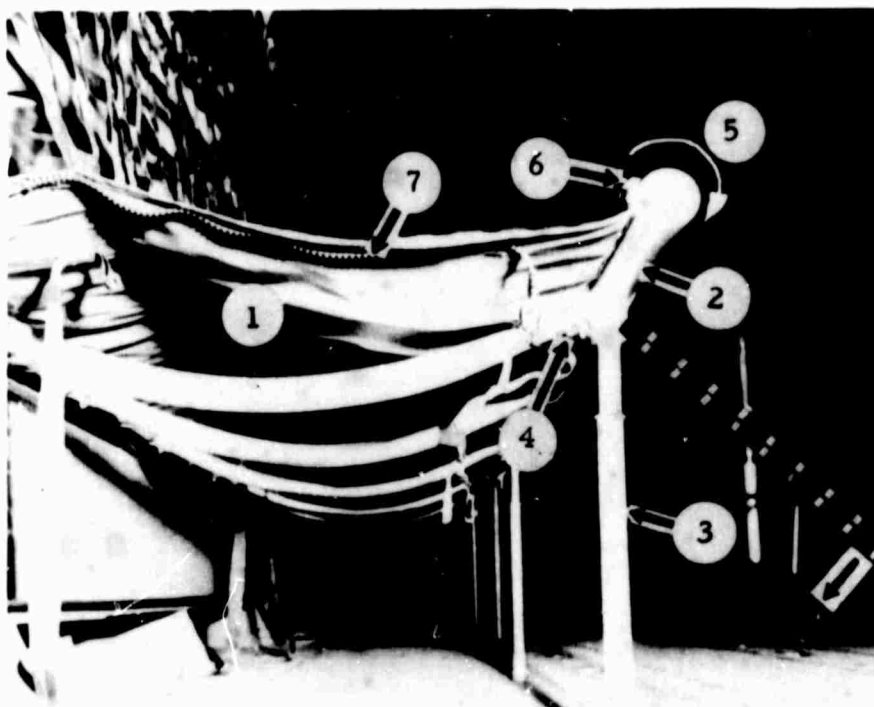


Figure 41. Troop seat being installed. Seat pan (1); forward beam (2); seat leg (3); friction lock (4); direction of rotation of seat leg (5) to pull seat pan taut before setting friction lock; forward beam locking pin mechanism (6); seat pan edge zipper (7).

The troop seats are set up for use by holding the seat leg in the position shown by the dotted line in Figure 41, tightening the friction lock (Figure 41-4) and then rotating the leg downward (Figure 41-5) and locking the legs into their floor attachment points. Rotation of the seat leg stretches the seat pan taut (Figure 42). When the seats are all in place, they are then interconnected by locking pins in the forward support beams (Figure 41-6) and by connecting the seat pans and seat backs with zippers (Figure 41-7).

Seat belts, which provide the only means of occupant restraint in the seats, are anchored to "O" rings which are attached to the brackets supporting the rear seat support beam. The "O" rings are shown in Figure 43, and the manner in which the seat belts are attached to the "O" rings is shown in Figure 44. It will be noted that portions of two seat belts (the right belt of one occupant and the left belt of the occupant in the next seat) are anchored to the same "O" ring.

Section III

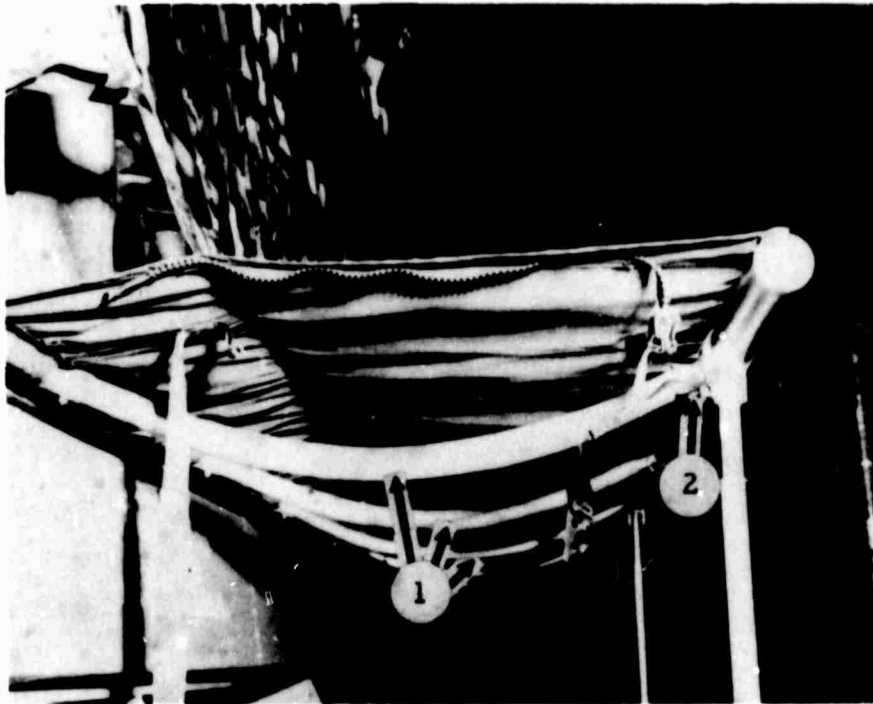


Figure 42. Seat pan material is drawn taut in process of installation. Crosstubes (1); friction lock (2).

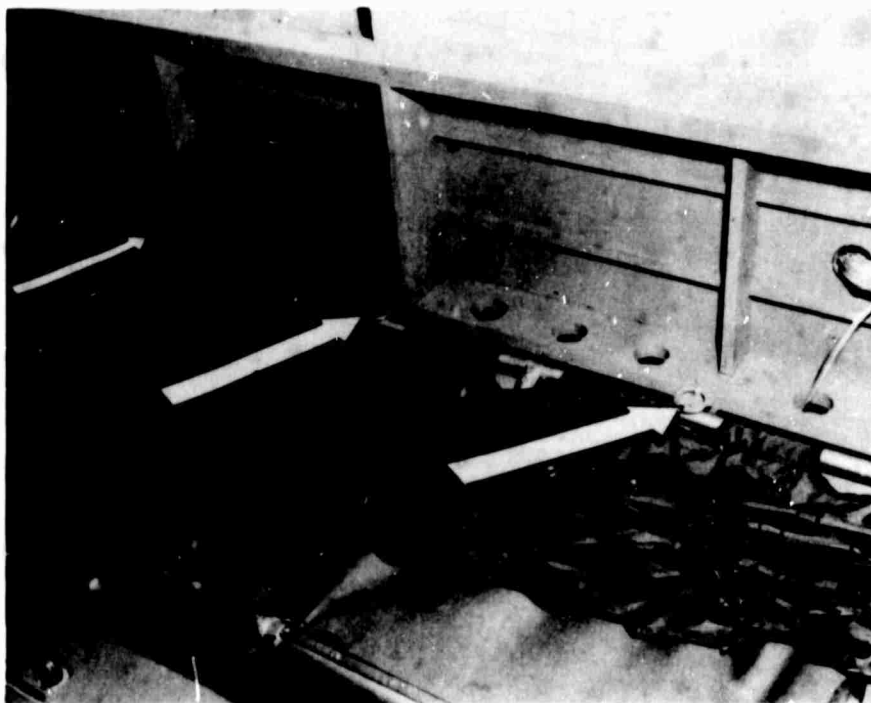


Figure 43. "O" rings at regular intervals between occupants (arrows).

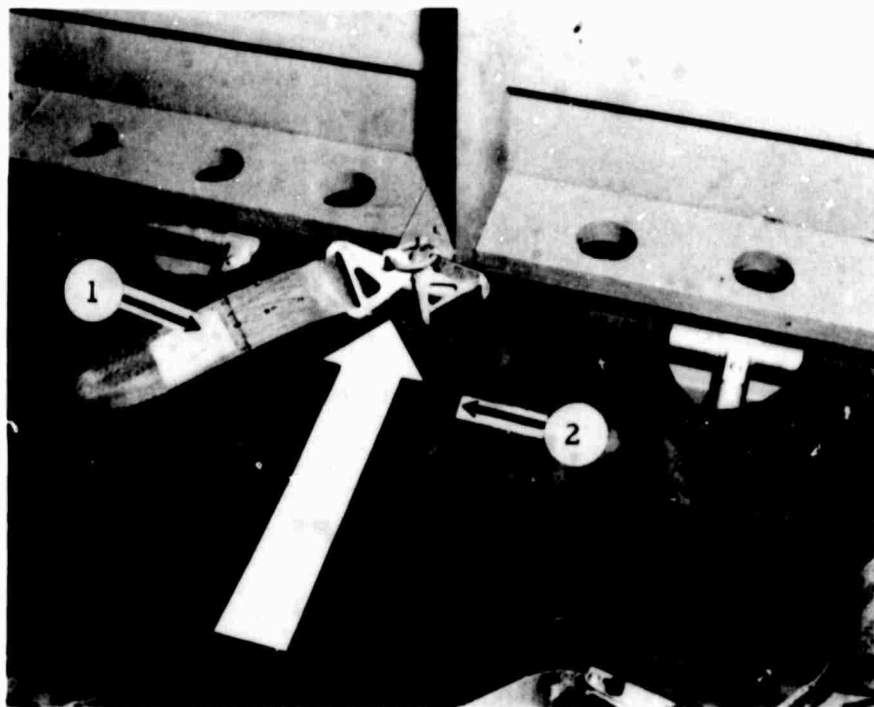


Figure 44. Safety belts (1 and 2).

The analysis of the troop seat being manufactured for this aircraft is based upon accident experience with seats manufactured to the same specifications. Although the seat is designed to meet the minimum requirements set forth in MIL-S-5705 (see Appendix II), it contains a number of deficiencies from a crashworthy point of view.

Accident experience has shown^{*} that this seat fails structurally when subjected to relatively moderate crash forces. When seats of this design fail, numerous injuries have been experienced as a result of broken, exposed ends of the tubing coming into contact with occupants, occupants being thrown free and coming into contact with other occupants and/or various parts of the aircraft.

* Discussed further under Analysis of Specifications and Deviations, Section IV.

Section III

(Figure 42-1) directly beneath his crotch. A more positive locking arrangement should be provided to prevent slippage which can result in this type injury.

Attention is invited to the manner in which the seat belts are attached to the "O" rings. Securing portions of two seat belts to a single attachment point (Figure 44) frequently results in failure of the anchorage due to the overload applied by two occupants. The seat belts, attached at points above the level of the seat pan, ride across the abdomen of the occupants (Figure 46).



Figure 46. Occupant seated on troop seat - seat back removed. Safety belt anchorage (1); longitudinal and vertical structural fuselage members (2); preferred position of safety belt (3).

LITTERS

Structure is provided in the cabin for mounting 24 litters. The litters are mounted along the cabin walls, allowing aisle width for loading from the ramp. Two one-man troop seats are provided for medical attendants.

Three stacks of four litters each are arranged along each wall of the cabin. They are mounted in brackets on two litter posts on the outboard (wall) and two litter straps on the aisle as shown in Figure 48.

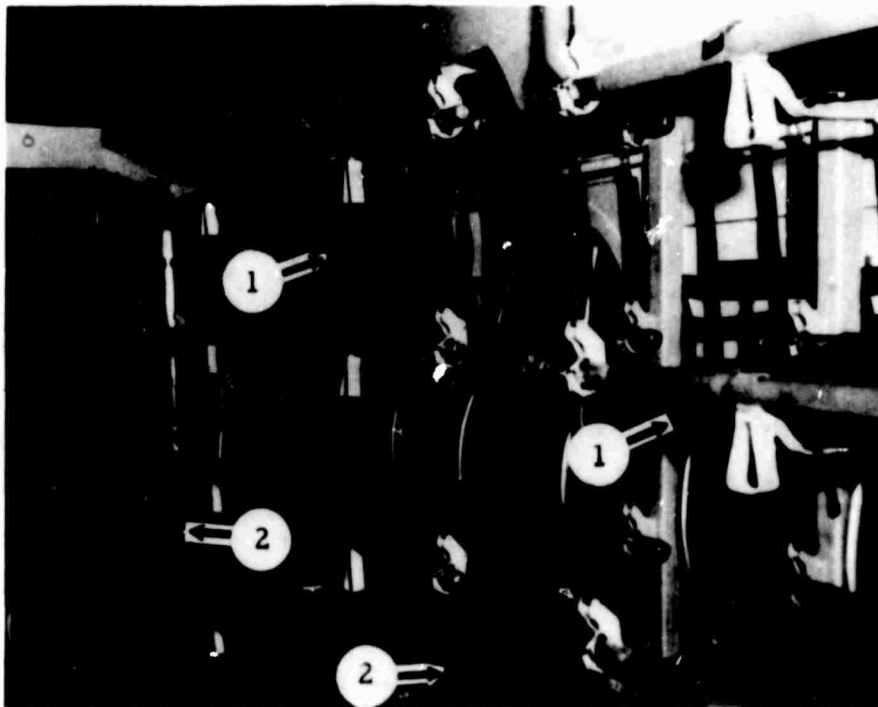


Figure 48. Litter installation. Litter posts (1); litter straps (2).

The litterposts are attached to studs in the upper seat support beam by means of a slotted anchor plate. The base of the post is attached to a floor anchorage. This arrangement is shown in Figure 49. The litter straps are anchored in the stowage compartment in the ceiling, as shown in Figure 50, and extend down to a floor anchorage, shown in Figure 51.

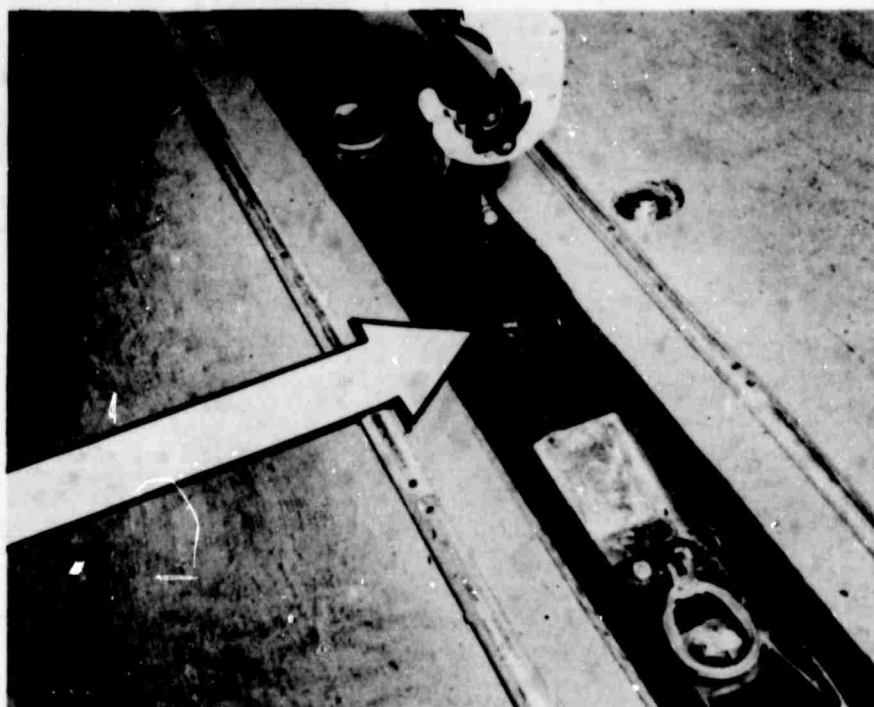


Figure 51. Litter strap floor anchorage.

It is difficult to evaluate the entire litter installation in terms of crashworthiness. Currently utilized litters are considered "field exchange" items in the military system. Of necessity, then, such litters must be strong, rugged pieces of equipment for use under field and combat conditions and must be suitable for use not only in aircraft, but also in ambulances, field hospitals, etc. Unlike components designed specifically for use in air vehicles, the litter itself is extremely heavy, bulky and presents many injurious structures when utilized in the manner required for mass evacuation of injured in transport aircraft.

A fully loaded stack of four litters creates an overall load with a center of gravity much higher than is experienced with the troop seat configuration. This load is supported primarily along the upper beam (Figure 49-1) and in the overhead area (Figure 50). Considering that helicopter accidents are usually associated with more vertical and side loading than longitudinal loading, the current minimum strength requirements do not seem to be realistic or compatible with the conditions

Section III

anticipated during even minimal crash decelerations. In addition, under dynamic crash force application, litter patients normally restrained in relatively loose fashion are likely to "bottom out" against their restraining system (belts, etc.), thereby magnifying peak forces which in turn are transmitted to the structures.

Litter installation requirements (MIL-S-5705 (USAF) - Appendix II) provide that supports and attachment fittings for litters shall be designed so that they will carry to the primary structure a 250-pound litter load, multiplied by the following ultimate load factors:

Forward	8 G
Side	± 1.5 G
Vertical	4.5 G down, 2.0 G up

While the adequacy of even 8 G strength in the forward direction is questionable, the side and vertical minimum strength requirements should be at least equal in helicopters.

Consideration should be given to re-evaluation of current minimum strength requirements as presented in MIL-S-5705 (USAF) and these requirements should be increased to a point where they are compatible with anticipated crash load conditions.

As an interim measure, the current litter configuration and installation in the YHC-1B should be dynamically tested with full-scale anthropomorphic dummies under force magnitude, direction and time history conditions associated with survivable crash loading in helicopters*, and the results of these tests should be utilized for the development of a more suitable specification.

EMERGENCY EXITS

Three emergency exits are located in the main cabin area. One of the exits consists of the upper portion of the main cabin door, which is a 36 x 40-inch jettisonable panel. Figure 36-2 illustrates this exit. The forward left window, located opposite the main cabin door, is mounted in a jettisonable 24 x 30-inch escape panel. Figure 52 is an external view of this exit. The third emergency exit is located in the

* Reference: Discussed in Analysis of Specifications and Deviations, Section IV.

Section III

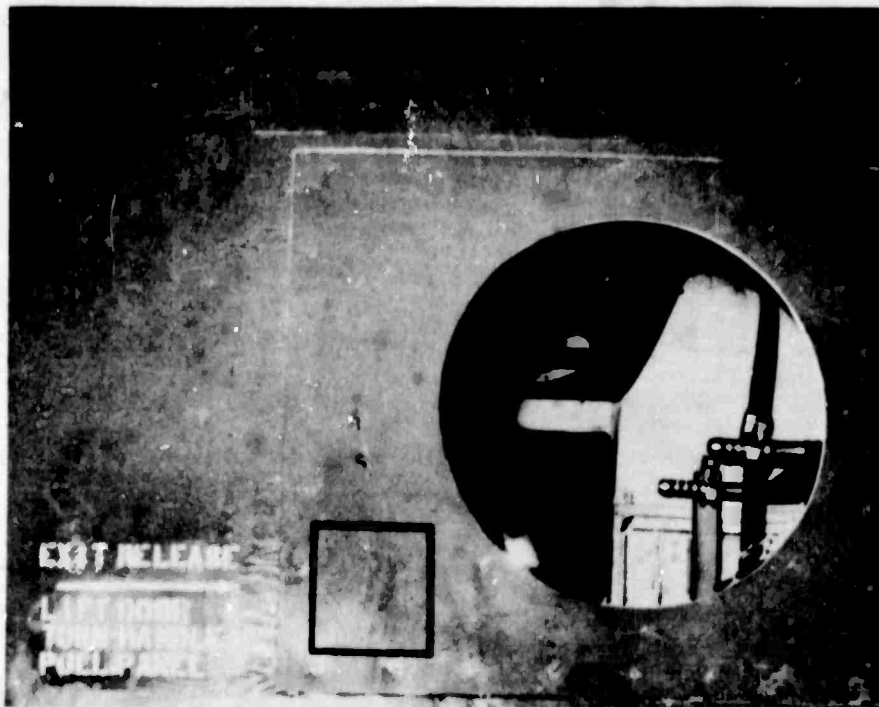


Figure 52. Emergency exit window opposite main cabin door (24 x 30-inch jettisonable panel).

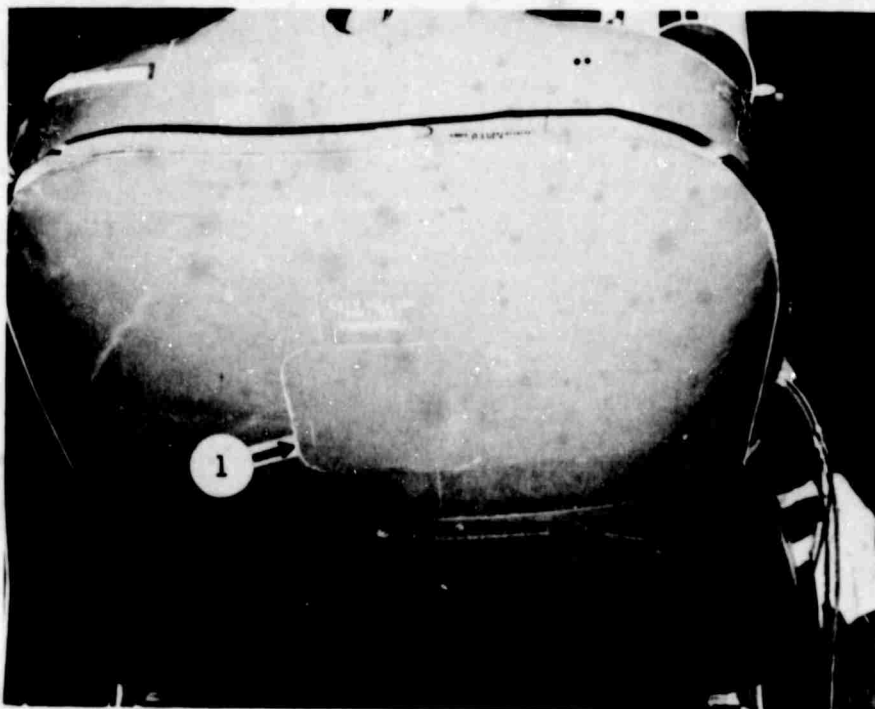


Figure 53. Loading ramp retractable cargo door. Emergency escape panel (1).

Section III

cargo door and is available for use when the loading ramp and cargo door are in retracted position. Figure 53 is an external view of the loading ramp showing the location of the exit. In addition to the three exits cited above, the third window from the front right-hand side of the fuselage is provided with markings "cut here". This window is located in an area which is free of heavy structural members and can be cut through with an axe from either the outside or inside of the aircraft to provide for an additional emergency exit. An external view of this area is shown in Figure 54. The hoist/rescue hatch in the center of the cabin floor (Figure 55) may be considered as a possible exit. Another possibility for escape is through the cargo door, if the door is opened prior to the accident or can be opened after the accident.



Figure 54. Third window on right side has "Cut Here" markings (emergency rescue area).

Section III

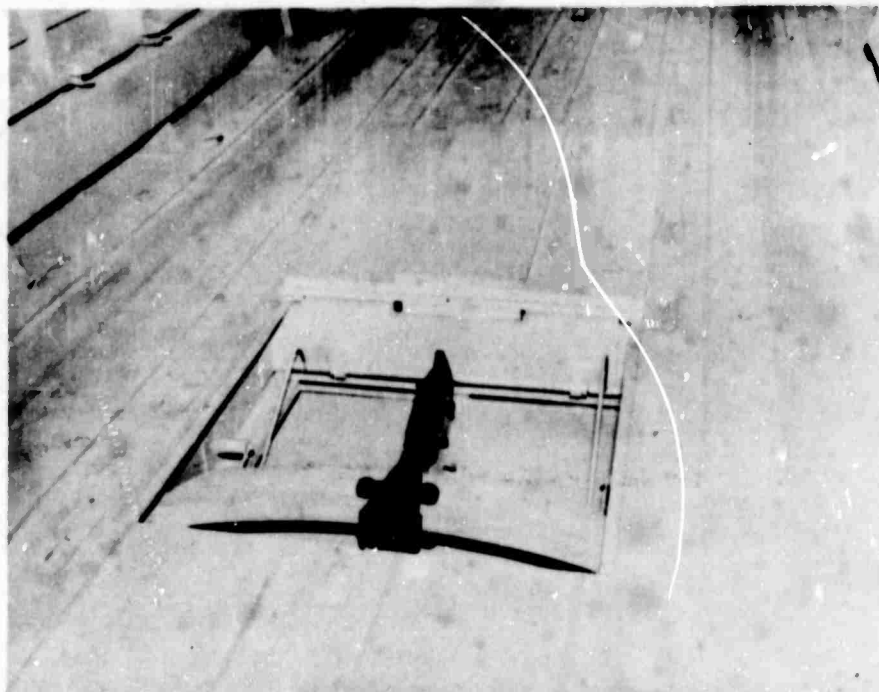


Figure 55. Hoist/rescue hatch in center of cabin floor.

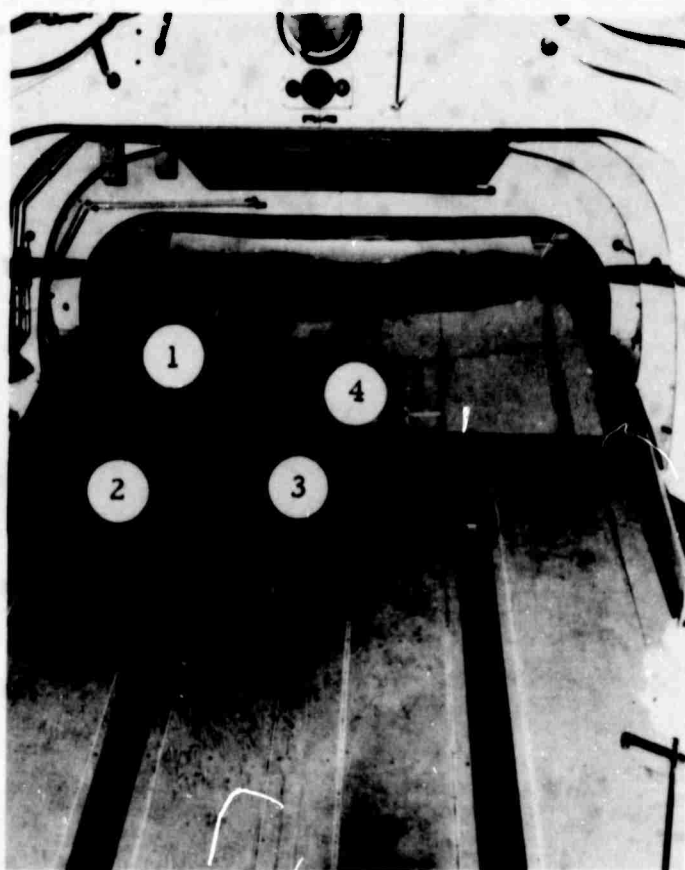


Figure 56. Cargo door (1) in closed position; ramp (2); ramp extension (3); emergency exit (4).

Section III

Before analyzing the escape provisions provided in this aircraft, reference is made to the following excerpts from the Handbook of Instruction for Aircraft Designers, paragraph 2.4.3.2, entitled "Location and Number of Emergency Escape Exits", (quoted in its entirety in Appendix I):

- a. "Inside the aircraft, locate emergency exits so it is not necessary to handle equipment, cargo, or furnishings to get out.
- b. "Extension of the alighting gear or opening of bomb-bay doors are not considered acceptable as normal emergency air exits, but may be used as supplements thereto.
- c. "Provide multiple place and cargo type aircraft with emergency exits located so that no more than three crew members will normally be required to use any one exit.
- d. "In aircraft where crew stations or compartments are widely separated or isolated or where partial failure of the aircraft components may cause isolation, provide each isolated station or compartment with an exit. Stations are considered widely separated when the distance between them is more than 8 feet. If the passageway which a crew member must traverse is at all restricted, make the distance less than 8 feet.
- e. "Provide all aircraft with a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching in 30 seconds by trained personnel representing the crew and all passengers.
- f. "In addition to the normal openings, clearly and visibly mark areas that can be chopped through with an axe. The number of such areas is dependent on the number of persons to be evacuated, their disposition in the aircraft, and the probability that 50 percent of the openings will be jammed.
- g. "Provide a holder for carrying an axe approximately in the center of the marked area and place a placard immediately adjacent, indicating its purpose. "

A review of the emergency exits provided in this aircraft reveals that there are only three normal exits available. The cargo door might possibly be used as an exit; however, it should be considered only as a supplement, since it is questionable whether the door can be readily opened after the crash, and there is always the possibility of this door being jammed during the accident. If open prior to the accident, there is also the possibility of its being blocked by such items as the ramp extensions (Figures 56 and 57). Another supplementary exit is the hoist/rescue hatch in the center of the cabin floor; however, the equipment installed in this hatch would require removal prior to use. It is questionable whether time would permit utilization of this hatch as an emergency exit.

Section III

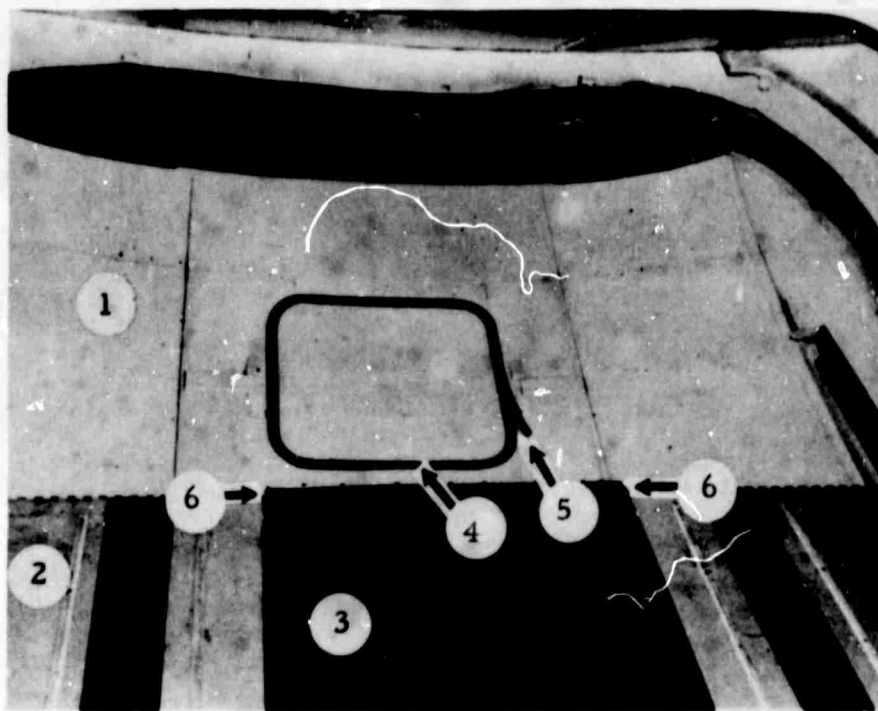


Figure 57. Closeup - Cargo door (1) in closed position; ramp (2); ramp extension (3); emergency exit (4); pull tab release (5); ramp extension hinge (6).

Note: Three ramp extensions will sometimes be utilized. There is no positive lock to prevent these extensions from swinging around to block the cargo door opening in the event the aircraft rolls onto its side.

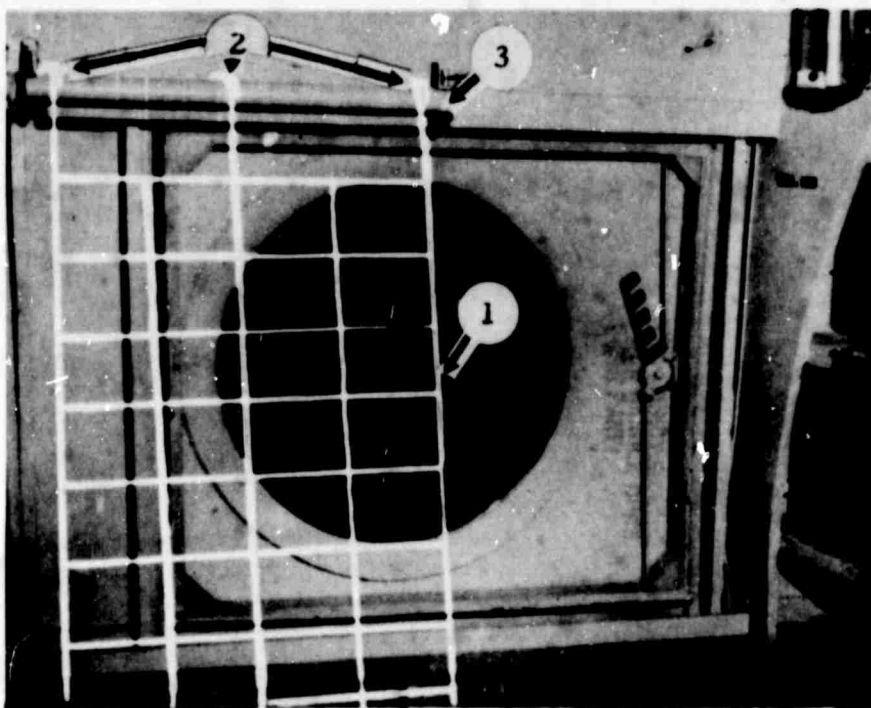


Figure 58. Front left cabin emergency exit (opposite main cabin door). Nylon troop seat webbing (1); upper attachments (2); upper beam (3).

Section III

With reference to the three normal emergency exits provided, HIAD states in quotation (c) above, that "emergency exits be located so that no more than three crew members will normally be required to use any one exit." Since 33 troops will occupy the main cabin area, this would require that 11 troops evacuate from each of the three available exits - nearly four times the number of troops recommended in HIAD. HIAD further states in quotation (f) above that "consideration should be given to the probability that 50 percent of the openings will be jammed." Due to the location of the exits in this aircraft, it is felt that two of the three exits will be available for use, with either the right or left exit being blocked by the aircraft's rolling on its side. This, then, would leave only two exits for the evacuation of 33 personnel, or more than 16 personnel per exit.

In quotation (e, above, HIAD states, "Provide all aircraft with a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 30 seconds by trained personnel representing the crew and all passengers." If the aircraft were on its side, with one exit blocked, it would be impossible for all personnel to evacuate in 30 seconds.

Reference is made to Appendix III in which NACA data is listed stating that available evacuation time in case of post-crash fire is from 7-1/2 seconds to 50 seconds maximum. In the event of a post-crash fire with this aircraft, it is unlikely that the troops could evacuate within these time limits.

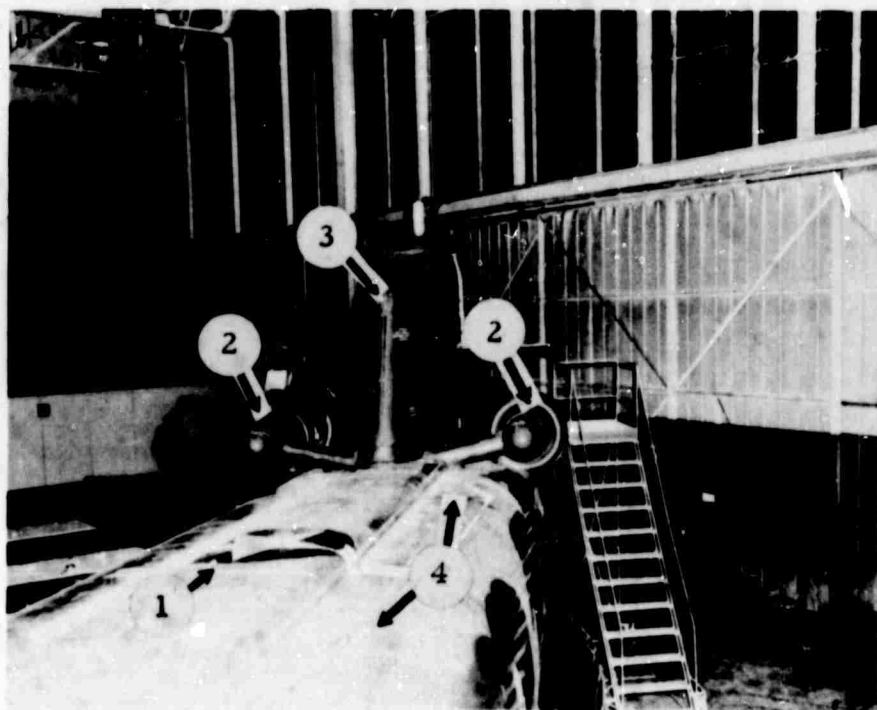


Figure 59. Top of cabin. Drive shaft tunnel (1); engines (2); aft pylon (3); possible area for overhead emergency exits (4).

Section III

Figure 58 illustrates the position of a troop seat partially blocking the emergency exit opposite the main cabin door. The time required to remove the troop seat webbing before the exit can be used in an emergency will further delay the evacuation of the troops.

With reference to the one area provided for cutting through with an axe (Figure 54), it is noted that no crash axe has been provided. Utilization of this area as an exit would require removal of the troop seat back before the area could be cut through from the inside and used for emergency escape. There is no placarding in this window on the inside of the aircraft.

Based upon the foregoing, the emergency exits provided in this aircraft are considered inadequate to accommodate the number of troops to be carried in the main cabin section. At least two more emergency exits should be provided on either side of the fuselage at the location of the window marked "cut here" and a window directly opposite on the left side. In addition, at least two emergency exits should be located in the roof structure, as illustrated in Figures 35 and 59. All other windows in the aircraft should be designed so they may be kicked out and the openings utilized as emergency exits.



Figure 60. Recessed hoist operating controls.

MISCELLANEOUS

The absence of significant protruding objects, which are generally noted in Army helicopters as injury-producing items in a crash, is a desirable crash safety design feature in this aircraft. Most of the cabin components and equipment installations are recessed (such as illustrated in Figure 60) or are out of striking range of the occupants.

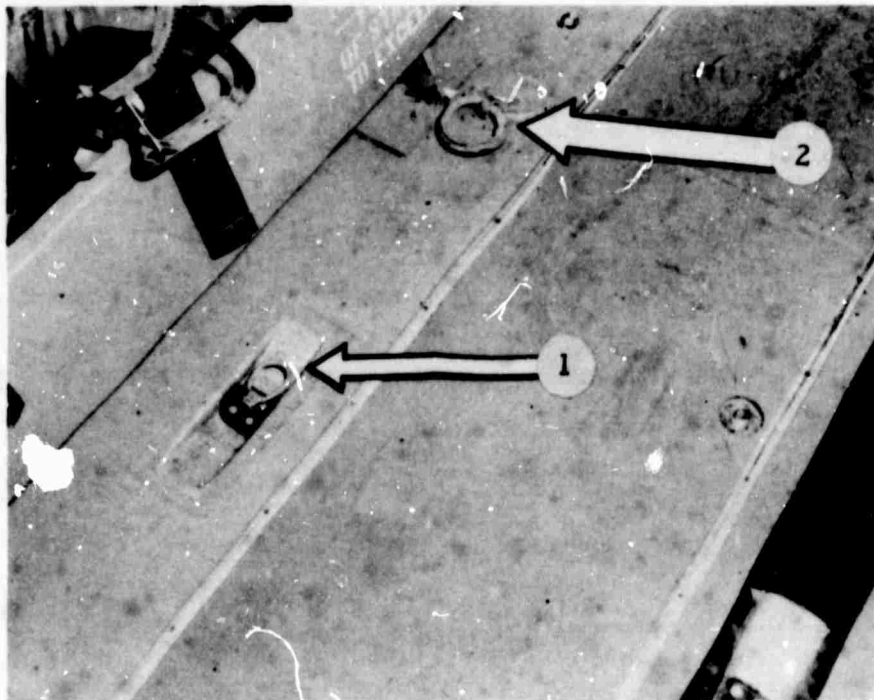


Figure 61. Cargo tie-down rings.

CONCLUSIONS

Based upon the foregoing evaluation of the main cabin, it is concluded that:

1. The troop seats are undesirable from a crash safety point of view.
2. The manner in which the occupants are restrained by seat belts is inadequate.

3. The tie-down and structural ability of the entire litter installation to withstand failure and structural collapse of entire assemblies does not appear to be compatible with anticipated survivable crash force conditions.
4. The number of emergency exits is inadequate to complete rapid evacuation of all occupants, particularly under post-crash fire conditions.
5. Provisions for emergency evacuation of the personnel from the main cabin would be improved by the addition of a crash axe and emergency lighting.
6. The emergency exit placarding on YHC-1B is inadequate.

RECOMMENDATIONS

It is recommended that:

1. The structural integrity and energy absorbing quality of the present seat design (if the present design is to be utilized) be increased in the seat itself, its anchorages, attachments, legs, braces, etc., and that the seat be subjected to dynamic testing.
2. The practice of using drilled holes and inserted locking pins in areas of seat structures (tubes) be eliminated in favor of using encircling clamps or brackets.
3. The safety belt anchorages be located 8 to 10 inches lower than they are presently located in order to align the belt across the pelvic area rather than across the abdomen. (It is most desirable to have the belt across the hips at an angle of about 45°.)
4. The safety belts be provided with individual self-aligning anchorages.
5. Rigid cabin structures within striking distance of cabin occupants be padded or shielded.
6. The specifications for Army aircraft litter installations be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration.
7. The number of emergency exits in the main cabin be increased as follows:
 - a. At least two overhead emergency exits be provided, such as those in the H-21 helicopter;
 - b. Two additional window exits be added;

Section III

- c. All other windows in the main cabin be designed so they can be kicked out in emergency conditions;
 - d. A quick disconnect for seat back webbing in front of the escape panel opposite the main cabin door be provided;
 - e. Provision for positive locking of the ramp extension in its stowed position be made to prevent blockage of the emergency exit in the cargo door.
- 8. The emergency exits be indicated by external placarding large enough and with sufficient contrast to be easily recognized as an escape area by untrained rescue personnel from a distance of approximately 100 feet.
 - 9. A black patch background be provided on all emergency escape areas inside the aircraft.
 - 10. The main cabin be provided with at least one crash axe for use during emergency escape conditions.
 - 11. All emergency exits be provided with independently powered emergency lighting that can be activated both manually and by impact. The automatic activation of the emergency lighting system in the event of an overall electrical system failure also be considered.

ANALYSIS OF SPECIFICATIONS AND DEVIATIONS

The following data and analyses refer primarily to Military Specifications and Requirements which form the basis for the design of the YHC-1B and to deviations from specified requirements and HIAD design instructions contained in a Vertol report. *

CRASH LANDING

1. Requirements

"Sufficient strength shall be provided in the seat installation and attachments of engines, transmissions, equipment, and useful load items (including fuel tanks one-half full) and their carry-through structure to prevent failure of such attachments which would result in injury to personnel. The ultimate inertia-load factors shall be those specified by the procuring activity. "

2. Deviation

"Applicable, except that the basic crash landing ultimate load factors for pilot and copilot seats shall be 8 G forward, 8 G downward, and 8 G laterally acting separately. Litter support structures shall be designed for a 250-pound litter load and as required by MIL-S-5705, paragraph 4. 7. 4. The troop seat supporting structure shall be designed in accordance with MIL-S-5804.

"The lap belt and supporting structure shall be capable of withstanding an ultimate load of 1,500 pounds acting at an angle of 45° upward, forward and inward. "

3. Reason for Change and Remarks

"The design load indicated above is similar to criteria for the H-21 and other VERTOL service helicopters. The value specified is generally consistent with the respective strength capacities of equipment items to be used in the YHC-1B. On the basis of service experience with previous models, these criteria are adequate to insure reasonable protection for personnel without incurring a prohibitive structural weight penalty. "

* Vertol Report No. 114-X-01 Rev. A, "Detail Specification for the Model YHC-1B Helicopter Transport, New Multi-Turbine - Twin Rotor. "

4. Analysis

Accumulated helicopter accident experience has indicated that present minimum strength and tie-down requirements are inadequate and incompatible with experienced survivable crash force conditions. Failures of flight crew member and passenger seats in current model helicopters, due to inadequate structural strength and tie-down requirements, have resulted in injuries and fatalities. Such injuries are inflicted when sharp exposed broken tubing, castings, etc., come in contact with the occupant and when seats fail at their attachments, allowing occupants to be thrown into forceful contact with other structures capable of inflicting injury or creating abrupt deceleration. Examples of these conditions are presented in Figures 62 through 67.

Although it would appear that the manufacturer has called for a greater degree of crash landing protection by specifying that pilot's and copilot's seats shall have 8 G load factors forward, downward, and laterally, the phrase "acting separately" detracts from the desirability of such correlation of load factors.

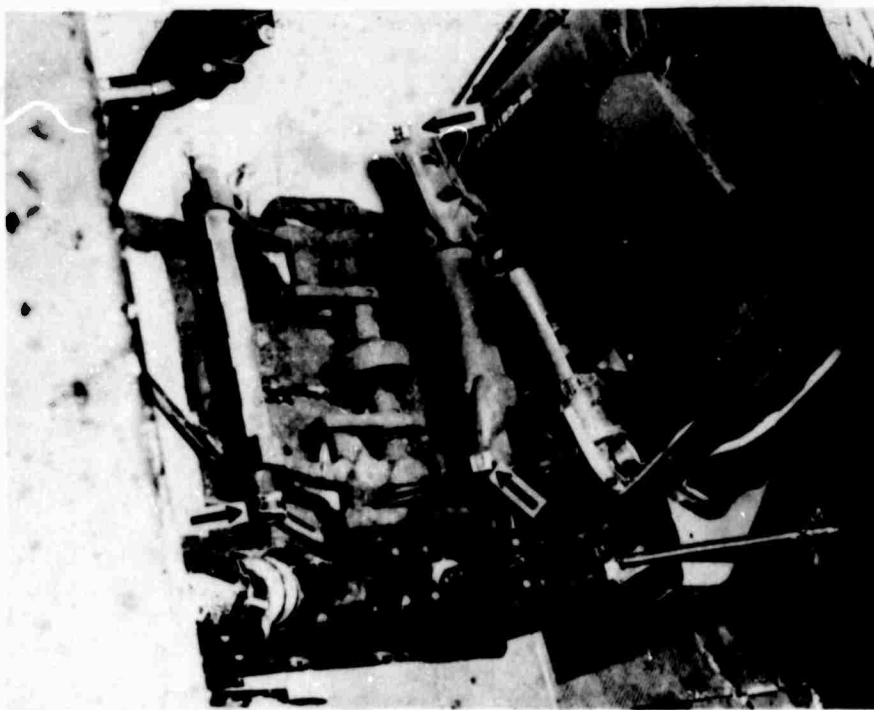


Figure 62. Illustration of pilot's seat failure in an H-21 accident (relatively moderate force - 8 to 12 G). When this seat failed, the occupant sustained abrasions and bruises of the left forehead, a fracture of the left arm and abrasions of the left arm and right leg.

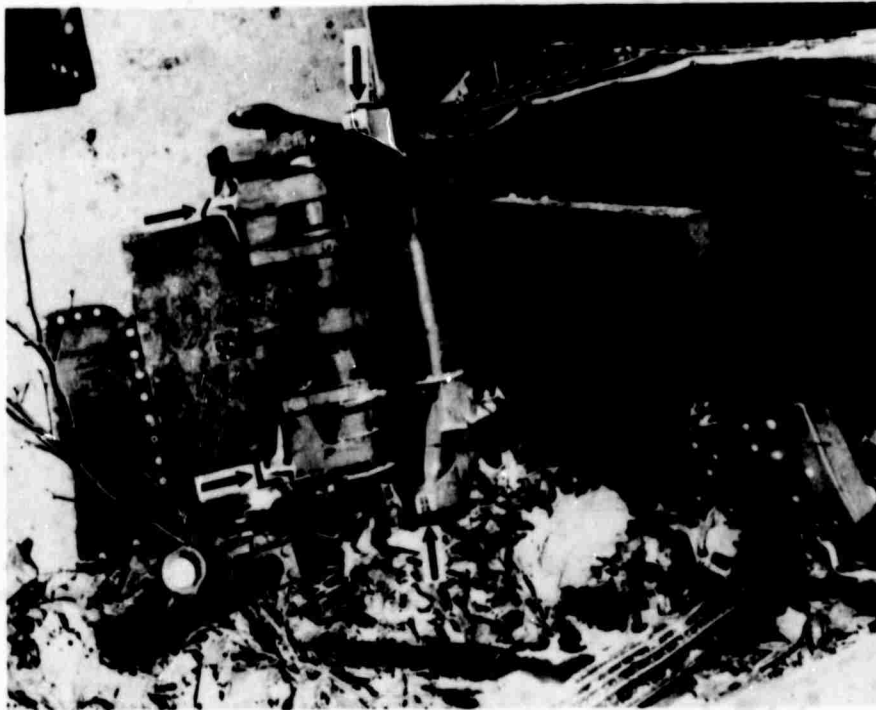


Figure 63. In this same accident, the copilot's seat failed, resulting in fatal injury.



Figure 64. Posed picture to show where copilot struck his head on the vertical support member (window frame), receiving fatal intercranial injury when his seat broke under side load.

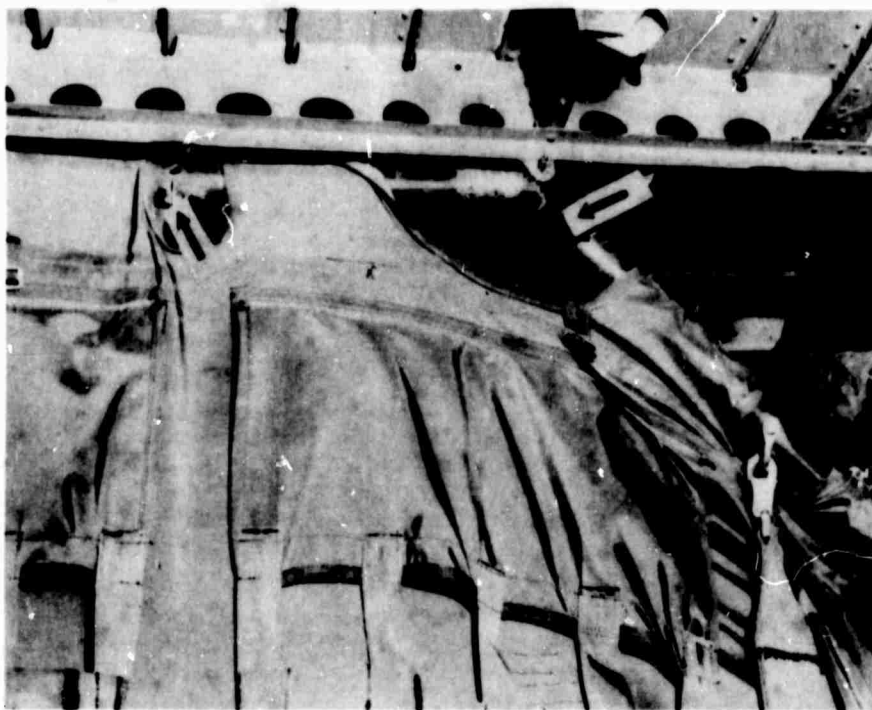


Figure 65. In this same H-21 accident, many troop seat failures occurred where tubular seat structure had been drilled for safety belt "D" ring mounting or pin attachment to the rail.

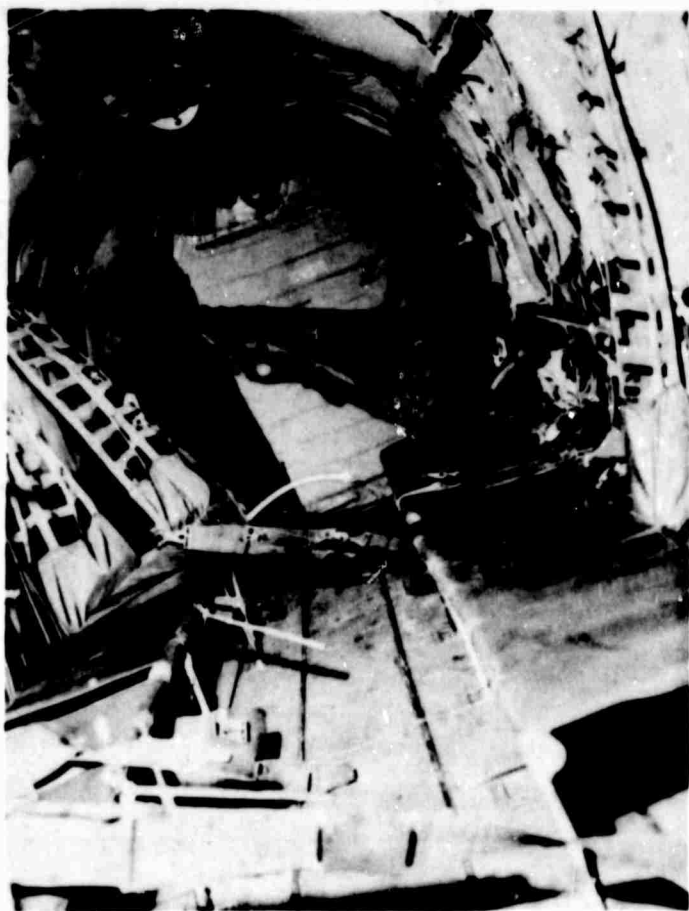


Figure 66. A number of seat structure, belt, anchorage and seat webbing failures occurred in this moderate impact accident, resulting in such injuries as concussion, fractures, lacerations, strain, and bruises. Note that failures occurred mainly in the areas of the rear beam, seat leg attachments, belt anchorages and webbings, and seat back attaching clips. Note, too, that floor, wall, ceiling structures have remained intact; a more crashworthy seat and restraint system would most likely have prevented any serious injuries.

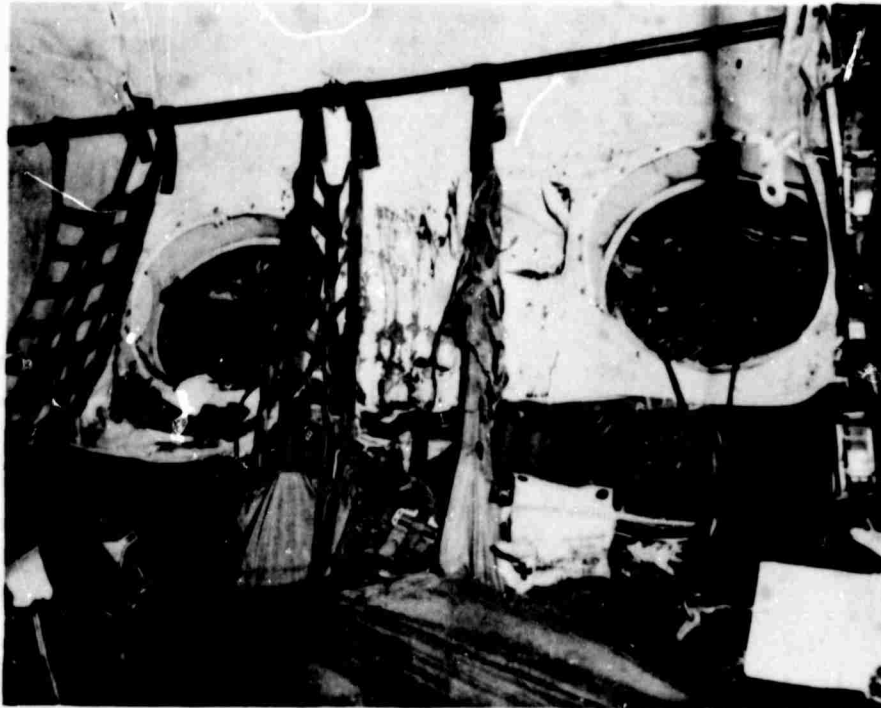


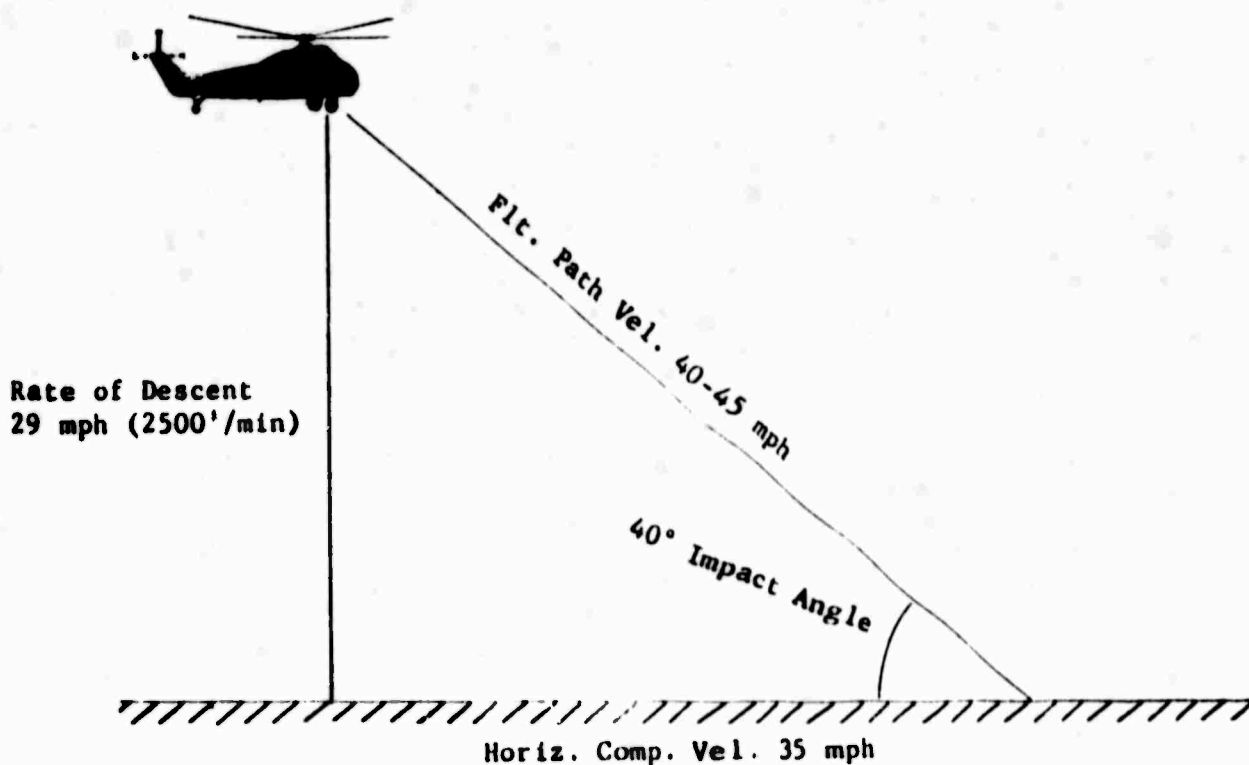
Figure 67. Another view of same accident showing troop seat damage.

(Figures 62 through 67 reference: U. S. Army H-21C Shawnee Helicopter Accident, Big Meadows, Virginia, 2 December 1959, Final Report, TREC Technical Report 60-14, AvCIR, 2713 East Airline Way, Phoenix, Arizona, February 1960.)

Section IV

Consideration should be given to a more realistic approach in the determination of minimum strength requirements: design strength, static testing, and dynamic testing should be more closely associated with the magnitudes, directions, time exposure, and rate of onset of the upper limits of survivable crash force conditions. Crash forces resulting from the following impact conditions, based upon a study of Army helicopter accident experience, should be considered:

- a. Flight path velocity* - 40-45 m. p. h.
- b. Horizontal component of velocity* - 35 m. p. h.
- c. Rate of descent - 2500 f. p. m. or 29 m. p. h.
- d. Angle of impact with the ground* - 40°
- e. Pitch angle with ground (nose up or down) - 20°
- f. Yaw to direction of flight path - 30°
- g. Roll angle - 20°
- h. Impact surface - smooth water or relatively level terrain which has the consistency of a sodded field.



* Assuming that a minimum stopping distance of 12 inches, in the direction of the crash force resultant, has been provided for the occupant.

Section IV

The deviation from crash landing requirements specified by Vertol also indicates a reduction in ultimate load strength of lap belt and supporting structures from 2,190 pounds (required in MIL-S-5705, paragraph 4. 7. 3) to an ultimate load of 1, 500 pounds.

A great number of troop seat failures and belt failures occurring to those troop seats designed in accordance with the military specification (2,190 pounds) have indicated an inadequacy in currently specified requirements. To reduce this requirement to 1, 500 pounds is undesirable. There is no reason to believe that crash loading in the YHC-1B will be any less in nature than has been experienced in the great number of currently utilized Army helicopters.

The deviation from crash landing requirements as specified by Vertol with regard to litter support structures does not appear actually to deviate from military specification requirements. However, it is believed that the entire litter installation system is inadequate and subject to gross failure under survivable impact force application because of:

- a. The design of currently utilized litters;
- b. The restraint system;
- c. The low order ultimate load factors specified.

Vertol states "on the basis of service experience with previous models . . . reasonable protection is offered personnel without incurring prohibitive structural weight penalties." Based upon "service experience", this is probably true; however, on the basis of accident experience, the prognosis indicated for a reasonable degree of protection would be to increase ultimate load strength and tie-down requirements.

Considering the impact conditions and factors presented herein, dynamic testing of the YHC-1B seats, supporting structures, components, and even the airframe itself should be conducted under conditions which simulate various combinations of the factors listed. This, then, will provide a sound engineering basis for establishing crash survival design criteria for rotary wing aircraft.

EMERGENCY LIGHTS

1. Requirement

Specification MIL- L-6503C (USAF), dated 13 May 1958, "Lighting Equipment Aircraft, General Specification for installation of, ". Paragraph 3. 3. 5 states ". . . emergency lights shall be provided

Section IV

to mark each emergency and natural exit in the cabins of all cargo and transport aircraft".

2. Deviation

Emergency lights shall not be provided.

3. Reason for Change and Remarks

Not required by U. S. Army military characteristics.

4. Analysis

HLAD Requirements (ARDCM 80-1: 2.4.2.5 - Appendix I) specifically provides for an independent emergency lighting system, operable by either a manual or a combination of manual and inertia-type switch, one emergency lighting unit at or near each emergency exit.

The need for emergency evacuation lighting was evidenced several years ago when CAB made mandatory the installation of evacuation lighting on all transport-type aircraft. This regulation also affects commercial helicopter operators throughout the United States. New York Airways, presently operating Vertol equipment, has installed emergency lighting systems to assist passengers in the evacuation from the aircraft should an accident occur at night. Chicago Helicopter Airways has complied with this regulation by incorporating similar lighting systems which are activated as a result of inertia forces. The new Sikorsky S-61 and S-62 are equipped with similar designs. It also is understood that the Vertol 107 includes emergency lighting as a part of its emergency equipment.

Considering certain similarities existing between anticipated military troop carrying operations and commercial transport operations (all weather, night, etc.), emergency lighting provisions facilitating emergency escape should be provided in the YHC-1B.

In addition to the manual/inertia-activated emergency lighting system, one additional feature is desirable. This would be a power failure feature to provide emergency lighting for both flight crew members and passengers in the event of an overall electrical system failure.

CONCLUSIONS

Based upon the foregoing comments, it is concluded that the specifications governing the design and construction of the YHC-1B are inadequate with reference to crew and troop seats, litter installation and emergency lighting, and are incompatible with experienced survivable crash force conditions.

RECOMMENDATIONS

It is recommended that:

1. The strength requirements, as outlined in MIL-S-5804B (USAF) and MIL-S-5705 (USAF) for troop seats and litter installations, be revised to increase minimum strength requirements to more realistic levels (compatible with experienced and anticipated upper limit survivable crash force application).
2. Crew and troop seats and litter installations be required to withstand, without failure, dynamic application of simulated crash force associated with upper limit survivable conditions.
3. The instructions set forth in the Handbook of Instructions for Aircraft Designers (HIAD ARDCM-80-1) be closely adhered to, particularly in those areas pertaining to crash landing, survival, escape, and emergency procedures.

BLANK PAGE

RECAPITULATION OF CONCLUSIONS

The conclusions set forth in the various sections of this report are recapitulated here according to section headings.

BASIC AIRFRAME (Section I)

After examination of the basic airframe of the YHC-1B, it is concluded that:

1. The basic airframe provides a crashworthy structure or capsule for protection of the occupants, provided the overhead structures are adequately stressed.
2. Structural analysis and/or dynamic tests should be conducted on certain elements of the basic airframe structure to assure its crashworthiness and to make certain that post-crash fire hazards are not present.
3. Several modifications should be made to eliminate positive post-crash fire hazards found during the evaluations.

CREW COMPARTMENT (Section II)

Based upon the evaluation of the crew compartment, it is concluded that:

1. Emergency exits in the crew compartment are adequate in number, type, and location.
2. Improved crash safety can be provided for the pilot and copilot by certain modification of the seat and shoulder harness installations and by padding areas within their immediate environment.
3. The crew chief/troop commander seat, its environment and restraining system is deficient from a crash safety point of view.
4. Installation of emergency lighting and a crash axe will facilitate emergency escape for the crew.

MAIN CABIN (Section III)

Based upon an evaluation of the main cabin, it is concluded that:

1. The troop seats are undesirable from a crash safety point of view.
2. The manner in which the occupants are restrained by seat belts is inadequate.
3. The tie-down and structural ability of the entire litter installation to withstand failure and structural collapse of entire assemblies does not appear to be compatible with anticipated survivable crash force conditions.
4. The number of emergency exits is inadequate to complete rapid evacuation of all occupants, particularly under post-crash fire conditions.
5. Provisions for emergency evacuation of the personnel from the main cabin would be improved by the addition of a crash axe and emergency lighting.
6. The emergency exit placarding on YHC-1B is inadequate.

ANALYSIS OF CERTAIN SPECIFICATIONS AND DEVIATIONS (Section IV)

Based upon review and analysis of certain specifications and deviations in the YHC-1B, it is concluded that the specifications governing the design and construction of the YHC-1B are inadequate with reference to crew and troop seats, litter installation and emergency lighting, and are incompatible with experienced survivable crash force conditions.

RECAPITULATION OF RECOMMENDATIONS

The recommendations set forth in this report are:

BASIC AIRFRAME (Section I)

Based upon the conclusions regarding the basic airframe, it is recommended that:

1. A thorough analysis and necessary dynamic tests be conducted to ascertain whether the forward and rear transmissions and the rotor support assemblies are adequate to prevent displacement of these units into occupied areas under survivable crash conditions.
2. Consideration be given to dynamic testing of the main landing gear, pod, and fuel cell arrangement to determine the capability of the fuel cells to resist rupture under survivable crash force conditions.
3. The support structure for the turbine engines be so designed as to allow the engines to break loose and be thrown clear of the aircraft during a crash.
4. The pressure fuel lines be routed away from the aft landing gear to eliminate a serious fire hazard.

CREW COMPARTMENT (Section II)

Based upon the evaluation of the crew compartment, it is recommended that:

1. The forward edge of the pilot and copilot seat pans be modified to provide for greater distribution (lower p. s. i.) of impact forces over a larger area of the thighs.
2. The forward end of the pilot's and copilot's seat tracks be provided with positive stops.
3. The mechanism for raising, lowering, and tilting the pilot's and copilot's seats be covered with a safety shield to prevent inadvertent contact with crew members' hands during seat adjustment.
4. The inertia reels of the pilot's and copilot's seats be attached to basic aircraft structure, rather than to the seats themselves.
5. Instructions be issued to operation, maintenance, and inspection personnel to assure that the nylon seat cover material has all its snap fasteners secured during flight.

6. The location of flight controls (pitch and cyclic controls) be modified in such a manner that they can be manipulated from a normal upright seated position.
7. The shoulder harness guide be reduced to the narrowest practical width.
8. The vertical support structure (forward edge of jettisonable exit) be padded with a high energy absorption material to prevent head injuries during forcible contact.
9. The jettisonable exit release handle be relocated or recessed in such a manner as to prevent forcible contact by the pilot or copilot and thus prevent inadvertent release during flight operation.
10. The lower edge of the instrument panel be shielded or padded with high energy absorption material.
11. The bulkheads behind the pilot's and copilot's seats be padded with high energy absorption material over the area within striking range of their heads.
12. The crew chief/troop commander's seat and supporting structures be tested dynamically to determine their ability to withstand survivable crash force conditions. (This seat should be subjected to and able to withstand the same G loads as the pilot's and copilot's seats.)
13. The crew chief/troop commander's seat be provided with a higher seat back with some means of upper torso restraint.
14. The structures within striking range of the crew chief/troop commander's head be padded with a high energy absorption material.
15. The crew compartment be provided with emergency lighting, an independent system activated both manually and by impact.
16. The crew compartment be provided with a crash axe secured in a safe manner and within ready access of the pilot, copilot, and crew chief.

MAIN CABIN (Section III)

Based upon the evaluation of the main cabin, it is recommended that:

1. The structural integrity and energy absorbing quality of the present seat design (if the present design is to be utilized) be increased in the seat itself, its anchorages, attachments, legs, braces, etc., and that the seat be subjected to dynamic testing.

2. The practice of using drilled holes and inserted locking pins in areas of seat structures (tubes) be eliminated in favor of using encircling clamps or brackets.
3. The safety belt anchorages be located 8 to 10 inches lower than they are presently located in order to align the belt across the pelvic area rather than across the abdomen. (It is most desirable to have the belt across the hips at an angle of about 45°.)
4. The safety belts be provided with individual self-aligning anchorages.
5. Rigid cabin structures within striking distance of cabin occupants be padded or shielded.
6. The specifications for Army aircraft litter installations be revised to provide strength requirements compatible with survivable crash force magnitudes, directions, and time duration.
7. The number of emergency exits in the main cabin be increased as follows:
 - a. At least two overhead emergency exits be provided, such as those in the H-21 helicopter;
 - b. Two additional window exits be added;
 - c. All other windows in the main cabin be designed so they can be kicked out in emergency conditions;
 - d. A quick disconnect for seat back webbing in front of the escape panel opposite the main cabin door be provided;
 - e. Provision for positive locking of the ramp extension in its stowed position be made to prevent blockage of the emergency exit in the cargo door.
8. The emergency exits be indicated by external placarding large enough and with sufficient contrast to be easily recognized as an escape area by untrained rescue personnel from a distance of approximately 100 feet.
9. A black patch background be provided on all emergency escape areas inside the aircraft.
10. The main cabin be provided with at least one crash axe for use during emergency escape conditions.
11. All emergency exits be provided with independently powered emergency lighting activated both manually and by impact. The automotive activation of the emergency lighting system in the event of an electrical system failure within the aircraft also be considered.

ANALYSIS OF SPECIFICATIONS AND DEVIATIONS (Section IV)

Based upon an analysis of certain specifications and deviations in the YHC-1B, it is recommended that:

1. The strength requirements, as outlined in MIL-S-5804B (USAF) and MIL-S-5705 (USAF) for troop seats and litter installations, be revised to increase minimum strength requirements to more realistic levels (compatible with experienced and anticipated upper limit survivable crash force application).
2. Crew and troop seats and litter installations be required to withstand, without failure, dynamic application of simulated crash force associated with upper limit survivable conditions.
3. The instructions set forth in the Handbook of Instructions for Aircraft Designers (HIAD ARDCM-80-1) be closely adhered to, particularly in those areas pertaining to crash landing, survival, escape and emergency procedures.

HANDBOOK OF INSTRUCTION FOR AIRCRAFT DESIGNERS

(HIAD - ARDCM 80 - 1)

--EXCERPTS--

2. 4. 2. 5 Emergency Lighting Provisions

Install emergency lighting provisions, independent of the aircraft's electrical system, in the cargo or passenger compartments of cargo and transport aircraft. An emergency lighting system that is self-contained, explosionproof, waterproof, and operable by either a manual or a combination manual inertia type switch is preferred. Provide one emergency lighting unit at or near each emergency exit. Submit installations using inertia type switches to WADC for approval.

2. 4. 3. 2 Location and Number of Emergency Escape Exits

In locating emergency exits on the aircraft, consider their proximity to such external items as propellers, turrets, gun barrels, radomes, antennas, and tail surfaces that may interfere with the crew members while abandoning aircraft. Inside the aircraft, locate emergency exits so that it is not necessary to handle equipment, cargo, or furnishings to get out. Do not locate the hatch centerline over 45 inches above secured equipment or structure which is capable of supporting a 250-pound crew member. Avoid the use of tunnels as means of reaching an exit. Do not make the access to or use of an exit dependent upon action by any other crew member. Extension of the alighting gear or opening of bomb-bay doors are not considered acceptable as normal emergency air exits, but may be used as supplements thereto. Provide multiplace - and cargo - type aircraft with emergency exits located so that no more than three crew members will normally be required to use any one exit. In aircraft where crew stations or compartments are widely separated or isolated, or where partial failure of the aircraft components may cause isolation, provide each isolated station or compartment with an exit. Stations are considered widely separated when the distance between them is more than eight feet. If the passageway which a crew member must traverse is at all restrictive, make the distance less than eight feet. In designing stations likely to become isolated, consider the possibility that heavy, massive equipment, such as gun turrets, cameras, and radar equipment, may become partially or completely detached from their supporting structures in a

Appendix I

crash landing or ditching and block passageways or emergency exits. Provide all aircraft with a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 30 seconds by trained personnel representing the crew and all passengers. In addition to the normal openings, clearly and visibly mark areas that can be chopped through with an axe. The number of such areas is dependent upon the number of persons to be evacuated, their disposition in the aircraft, and a probability that 50 percent of the openings will be jammed. Arrange such areas so that a minimum of four feet fore and aft separates right and left location. Provide a holder for carrying an axe approximately in the center of the marked area, and place a placard immediately adjacent indicating its purpose.

APPLICABLE MILITARY SPECIFICATIONS

MILITARY SPECIFICATION: MIL-S-8698(ASG)

3.4.7 Crash Landing - Sufficient strength shall be provided in the seat installation and attachments of engines, transmissions, equipment, and useful load items (including fuel tanks one-half full) and their carry-through structure to prevent failure of such attachments which would result in injury to personnel. The ultimate inertia-load factors shall be those specified by the procuring activity.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.2 Passenger Seats - Passenger seats shall be designed to the load requirements of Spec MIL-S-5797 (USAF). All attachments and supports shall have sufficient strength to withstand the seat design loads.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.3 Troop Seats - Troop seats and supporting structures shall be designed to the load requirements of Specification MIL-S-5804 (USAF). Troop seat lap belts and their attachments to the airplane structure shall be capable of carrying an ultimate load of 2,190 pounds acting at an angle of 45° upward, forward, and inward. Troop seat shoulder harnesses and their attachments to the airplane structure shall be capable of carrying an ultimate load of 1,260 pounds acting horizontally at an angle of 45° forward and inward.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.4 Airplane Litter Installation - Supports and attachment fittings for litters shall be designed so that they will carry to the primary structure a 250-pound litter load, multiplied by the ultimate load factors specified below, acting separately.

Forward	8 G	Vertical	4.5 G (down)
Side	† 1.5 G		2.0 G (up)

Appendix II

MILITARY SPECIFICATION: MIL-S-8698 (ASG)

3.1.1 Strength - The entire helicopter structure, including beaching units and hoisting sling, where applicable, shall be capable of supporting without failure the ultimate loads resulting from the loading conditions and ultimate factor of safety specified in Section III, and shall be capable of withstanding without failure the repeated load and endurance tests of Specification MIL-T-8679. Allowable stress values to be used in the stress analyses shall be those taken from approved Government publications, such as Bulletin ANC-5, or various NACA or Bureau of Standards reports, whenever possible.

MILITARY SPECIFICATION: MIL-T-8679

3. REQUIREMENTS

3.1.2 Addition of tests - If the tests required by the contract, to be performed by the contractor, are inadequate to prove that the helicopter meets the specified design requirements, the contractor or the procuring activity shall propose amendments to the contract to include tests which will prove adequately that the structure incorporates specified strength and rigidity.

CRASH SAFETY CRITERIA

In its efforts to determine the crash survival aspects of aircraft accidents AvCIR, a Division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft occupants. The same criteria are also used to evaluate the crash safety features of mock-ups and prototypes.

CRASHWORTHINESS

Crashworthiness may be defined as the ability of basic aircraft structure to provide protection to occupants during survivable impact conditions. Impact conditions are considered survivable in that part of the cockpit/cabin area where the crash forces are within the limits of human tolerance (with minimal or no injury)* and where surrounding structure remains reasonably intact.

Lack of crashworthiness, generally, indicates that the basic aircraft structure, seen as a protective container, is subject to extensive inward collapse thereby affecting the "inhabitability" of this area. Typical in this respect are (1) the rearward movement of the engine in single engine aircraft; (2) the downward displacement of transmissions and other heavy components in helicopters; (3) the upward collapse of lower structures into the cockpit/cabin area. This deformation or collapse of the occupiable area may result in crushing type injuries or trapping of the occupants.

When evaluating the crashworthiness of basic aircraft structure, stress is placed upon the expected behavior of this structure during a survivable type impact. Attention is also given to anticipated dynamic response under the most probable conditions of impact angle and aircraft attitude, based upon accumulated past experience. This facilitates an appraisal of the possibility of displacement of certain heavy components into the occupiable area as a result of inertia forces.

* Approximately 40 G transverse to the spine, 25 G parallel to the spine (positive G), 15 G parallel to the spine (negative G) with due consideration for peak magnitude, duration, rate of onset, and method of body restraint. J. P. Stapp, Human Exposure to Linear Deceleration, Part 2. The Forward-Facing Position and the Development of a Crash Harness. Wright Air Development Center, Wright-Patterson Air Force Base, Dayton (Ohio), December 1951. A. F. Technical Report No. 5915, Part 2.

TIE-DOWN CHAIN

Although a crashworthy structure provides primary protection during a crash deceleration, injuries may still occur when occupants are allowed to come into forceful contact with their environment or to be struck by loose objects thrown through the occupiable area. The restraint system used to prevent occupants, cargo, and components from being thrown loose within the aircraft is commonly referred to as the tie-down chain. The occupant's tie-down chain consists of: seat belt, seat belt anchorage, shoulder harness and anchorage, seat structure, seat anchorages, and floor. Failure of any link in this chain results in a higher degree of exposure to injury.

Accident statistics indicate that the site of most serious and frequent injury in general aviation accidents is the head. In most cases, this is due to lack of restraint, allowing the head to gain momentum during impact and to strike objects in its path with a force exceeding that of the overall crash deceleration. This is especially true in the case of cockpit occupants who face the instrument panel, control wheel, and many other injurious environmental structures. Considering these factors, it is practically impossible to avoid contact injuries during crash deceleration when such occupants are not restrained by a properly installed and properly used shoulder harness of adequate strength in combination with a seat belt.

Although seat structure and anchorages meet static strength tie-down requirements, failures frequently occur as a result of dynamic loads imposed by the occupants on seat belts and shoulder harnesses when these are anchored to the seats instead of primary structure. This type of crash force amplification should be taken into consideration when evaluating the dynamic strength of the occupant tie-down chain. Inadequately or improperly secured aircraft equipment and components in the occupiable area also have an injury potential during crash decelerations. Therefore, the tie-down and stowage of such items as luggage, cargo, radio equipment, fire extinguishers, and tool boxes requires careful consideration.

OCCUPANTS' ENVIRONMENT

Accident experience has shown that under many impact conditions occupants who are reasonably restrained within a crashworthy structure may still receive injuries through forceful contact with injurious environmental structures, components, etc. (This is particularly true when shoulder harness is not used.) The freedom of movement of the

occupant's body during a crash deceleration is governed by the type of restraint system installed and the manner in which it is used. Generally, it can be stated, however, that injuries resulting from the flailing action of the occupant's body show a peripheral trend; that is, the areas farthest away from the seat belt receive most of the injuries (head and lower extremities).

To preclude the probability of injury through striking injurious environment, the limitations of the restraint system should be used as a guide for the extent to which the occupant's environment should be made harmless. The injury potential of all objects and structure within striking range, omni-directionally, can be reduced to a minimum by such measures as elimination of sharp surfaces, safety-type control wheels, breakaway features in instrument panels, use of ductile or energy absorbing material wherever possible.

TRANSMISSION OF CRASH FORCE

Another independent injury-producing factor presents itself in the fact that crash forces may be transmitted or even magnified through rigid aircraft structures. This is usually associated with "bottoming out" on structures incapable of absorbing or reducing crash force. Although crash force in most accidents is applied in a direction oblique to the occupant's spine, it is customary to resolve vertical and horizontal components of the crash force resultant and relate these to the human G-force tolerance levels, either parallel or transverse to the spine. A normally seated person, when effectively restrained by a seat belt and shoulder harness, can tolerate (with minimal or no injury) approximately 40 G transverse to the spine, 25 G parallel to the spine in the foot-to-head direction (positive G), 15 G parallel to the spine in the head-to-foot direction (negative G).

Injuries attributed solely to transverse G will seldom be encountered in aircraft accidents, because collapse of structure and/or failure of the restraint system will most likely occur before the limit of transverse G tolerance (40 G) is reached. This is an undesirable situation. Although operational and economic considerations impose limits on the overall fuselage strength, the occupant tie-down chain should be more compatible in strength with tolerance levels of the body.

Accident experience has shown that injuries directly attributed to the transmission or magnification of crash force are usually associated with predominantly vertical impacts. Vertebral injuries are most often associated with vertical crash force application.

Appendix III

The seat, as the occupant's supporting structure, and the underlying floor structure are the media through which vertical forces are usually transmitted to the occupant. The dynamic response of these media during an impact determines the manner in which the forces acting on the aircraft structure can be modified before reaching the occupant. An extremely rigid structure, which normally is not found in aircraft, would transmit the forces without modification. An elastic structure, which has energy-storing properties, may modify the magnitude and other characteristics of decelerative force to the extent that amplification takes place. For example, a foam rubber cushion (which does not offer an appreciable resistance to compression) allows an occupant to "bottom out" against rigid seat and seat pan structures during a vertical impact. A more desirable situation would be that in which the structure between the occupant and the point of impact had high energy absorbing characteristics. This may be achieved by the use of structure which collapses progressively without failing suddenly. This ideal form of crash energy absorption results in attenuation of the crash forces transmitted to the occupant. It is one of the basic methods for the incorporation of occupant protection in aircraft design.

POST-CRASH FACTORS

Although a distinction could be made between the prevention of injuries sustained in the dynamic phase of the impact and those sustained in the post-crash events, it is felt that the overall crash survival concept does not allow this distinction. Past experience has shown that accidents involving only very minor impact forces can become catastrophies as a result of post-crash factors.

One of the greatest hazards in an otherwise survivable accident is the possibility of a post-crash fire. These fires, normally, are of a sudden nature and may severely restrict the time available for evacuation. According to a NACA study (Technical Note 2996) not more than 50 seconds may be available for escape in all but the most severe fires, although in some cases passengers must move away from areas of burned-through fuselage in as few as 7-1/2 seconds. This time element becomes even more critical when occupants are handicapped by such factors as disabling injuries, stunned condition, unfamiliarity with the seat belt release or the operation of the emergency exits, being trapped, and panic.

Control of post-crash fires, to some extent, is governed by design (location of fuel cells and fuel lines in relation to electrical and mechanical ignition sources; resistance of fuel system components against rupture

Appendix III

under conditions of moderate crash forces or distortion). Other preventive measures include location of fire extinguishers at strategic points and automatic emergency or impact-operated fire extinguishing systems.

In the event of a post-crash fire or a ditching, the ability of all occupants to timely evacuate the aircraft probably becomes the most important survival factor. The evacuation time is a function of the number, location, and adequacy of the normal and emergency exits. * The location and emergency operation of normal and emergency exits should be obvious even to the non-experienced passenger. Hand or impact-operated emergency lights can be of vital importance during evacuation in conditions of darkness or subdued light.

* HIAD (the military Handbook of Instructions for Aircraft Designers) requires "a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 30 seconds by trained personnel representing the crew and all passengers."